CUTTING AND GRAZING SYSTEMS FOR GRASS / WHITE CLOVER *Trifolium repens* L. ASSOCIATIONS

A Thesis submitted to the University of Glasgow for the Degree of Doctor of Philosophy in the Faculty of Science

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ABBREVIATIONS

CG	Continuous grazing / stocking
cm	centimetre
D or Dip	Diploid
DANI	Department of Agriculture for Northern Ireland
DM	Dry matter
E	Early (of grass maturity)
F pr.	Probability
Fig	Figure
g	gramme
ha	hectare
HFRO	Hill Farming Research Organisation
I	Intermediate (of grass maturity)
kg	kilogramme
K_2O	Potash
L	Large (of white clover leaf size)
L	Late (of grass maturity)
LAI	Leaf area index
LSU	Livestock unit
M	Medium (of white clover leaf size)
m	metre
mm	millimetre
N	Nitrogen
NDF	Neutral Detergent Fibre
NIAB	National Institute of Agricultural Botany
P	Probability
P_2O_5	Phosphate
PRG	Perennial ryegrass
REE	Relative ear emergence
S	Small (of white clover leaf size)
SAC	Scottish Agricultural College

SED	Standard Error Difference
SSH	Sward Surface Height
T or Tet	Tetraploid
UK	United Kingdom
VE	Very early (of grass maturity)
VL	Very late (of grass maturity)
VL	Very large (of white clover leaf size)
*	($P < 0.05$)
**	($P < 0.01$)
***	($P < 0.001$)

SUMMARY

The thrust of advice and progressive farming thought over the past three decades has been to encourage systems of grass production based on the optimum response of grass to inorganic fertiliser nitrogen and achievement of maximum economic yields per hectare.

Recent public pressure, supported by government and EC initiatives has provoked interest in low input, less intensive systems of sustainable agriculture. The role of white clover within grass / white clover swards which receive no inorganic nitrogen, is seen as pivotal to lower input forage based livestock and mixed farming systems. This is due to white clover's high nutritive value, symbiotic ability to "fix" atmospheric nitrogen and potential to produce yields of forage equivalent to "grass only" swards receiving moderate inputs of fertiliser nitrogen.

This move away from traditional high input systems has highlighted the need for detailed prescriptions for the composition and management of grass / white clover swards as a viable and reliable alternative. In this project two experiments were conducted to address the two areas of sward composition and sward management which were considered to be major limiting factors to the attainment of reliability in white clover based animal production systems.

In both experiments reported in this thesis the hypotheses being tested were:

1. The white clover component of a continuously sheep stocked grass / white clover sward is enhanced by the imposition of a rest from grazing for a conservation cut.

2. The presence and survival of white clover in a continuously stocked grass white clover sward is determined by the specific / varietal characteristics of the sward components and their combined response to management.

Experiment 1 was set up investigate the management of perennial ryegrass / white clover associations over the range of perennial ryegrass maturity and ploidy in association with white clovers of different leaf size. The management system tested was continuous stocking

with sheep and the effect and optimum timing of a rest for a conservation cut. Due to the large number of treatments investigated, this was a small plot grazing trial and detailed measurements of sward composition, architecture and white clover development were made using a variety of non destructive techniques including the use of point quadrat, grid quadrats and individual stolon measurements.

Experiment 2 was set up to study the effect of similar management options on other important perennial grass species / medium leaved white clover swards and compare the findings with those for both diploid and tetraploid perennial ryegrass associations. This experiment was on a field scale and sward cores were used to measure white stolon parameters and sown and weed grass tiller numbers. Production under grazing was assessed using exclosure cages and "grazing days".

In both experiments, conservation yields were assessed and grazing management was based on sward height with stocking rates adjusted using "put and take" ewes and lambs and in the case of experiment 1, buffer grazing.

Both experiments demonstrated that continuous sheep stocking of grass / white clover swards does not necessarily have an adverse affect on white clover proportions within the sward. Experiment 1 showed with small leaved white clover, hard grazed to a sward height of 45 mm, high sward white clover proportions can be maintained. Likewise experiment 2 demonstrated that at a sward surface height of 60 mm, satisfactory white clover proportions were achieved using medium leaved white clover in association with each of tetraploid perennial ryegrass, diploid perennial ryegrass, meadow fescue, cocksfoot and timothy.

With the exception of the meadow fescue / white clover association, a rest from continuous stocking to take a conservation crop at normal first cut time (April to late May) greatly reduced the proportion of white clover, compared with that in the unrested treatment, within associations of these perennial grasses with medium leaved white clover. In the case of the meadow fescue / white clover association the reduction, though present was small. In the perennial ryegrass / white clover associations, the reduction was greater (though not significantly) in the diploid perennial ryegrass association than in the tetraploid association and also increased with both white clover leaf size and lateness of perennial ryegrass variety.

A later rest from continuous sheep stocking during late June to early August enhanced the proportions of medium leaved white clover within the diploid perennial ryegrass association but had little effect on the proportion of white clover in the meadow fescue / white clover association. The proportions of medium leaved white clover in the tetraploid perennial ryegrass, cocksfoot and timothy associations were reduced with this later rest.

In densely tillered diploid perennial ryegrass / white clover swards under continuous stocking, white clover proportions can be limited. In similarly grazed tetraploid perennial ryegrass swards, the sward is open enough to allow the maintenance of satisfactory proportions of white clover. With continuously stocked meadow fescue / white clover associations, the sward is so open that white clover becomes dominant and the survival of the sown grass is jeopardised. With continuously stocked cocksfoot / white clover swards, the effects of both grass tiller number, size and coarseness and preferential grazing of white clover limit white clover development. In timothy / white clover swards, the acceptability of the grass to sheep results in reduced grazing pressure to maintain sward surface heights. This reduced grazing pressure, while aiding tiller survival, encourages white clover development.

It was concluded that a tetraploid perennial ryegrass / small or medium leaved white clover is the best mixture for continuous sheep stocking where no mid to late summer rest is practicable. However, in wet conditions on a few heavier soil types, this type of open sward is particularly susceptible to soil contamination and stolon burial. Here a diploid perennial ryegrass / white clover sward could be considered, with the option of imposing a late June to early August conservation rest to maintain the proportion of white clover in the sward. In a more extensive situation, a less productive timothy / white clover sward could provide highly acceptable, clover rich grazing with the opportunity of a heavy highly digestible early August silage cut. This type of sward would also be appropriate for wetter conditions due to its more prostrate habit than a tetraploid perennial ryegrass sward. Care would have to be taken not to over graze the sward in order to avoid extensive "bulb pull".

CHAPTER 1

MANAGEMENT OF GRASS / WHITE CLOVER *Trifolium repens L.* SWARDS.

REVIEW OF LITERATURE

CHAPTER 1

MANAGEMENT OF GRASS / WHITE CLOVER *Trifolium repens L.* SWARDS.

1.1 INTRODUCTION AND GENERAL REVIEWS

In recent years, the apparent over-production of many food commodities within the European Community and other parts of the developed world has caused a change in agricultural policies on the part of governments. This has resulted in the withdrawal of support in some sectors, the imposition of quotas in others and the introduction of inducements to remove land from food production. At the same time private lobby groups, public interest bodies, the general public and governments are increasingly aware of animal welfare issues, the destruction of non-renewable resources and environmental damage for which some of the blame is currently attributed to intensive, high input systems of food production.

For the producer, who for decades has worked on the premise that if he wishes to increase profit, all that is needed, within obvious limits, is an increase in production, the "goal posts" have moved. Simple targets for optimum fertiliser nitrogen levels based on farm location, soil type and summer rainfall which have been researched, developed and improved over the last two decades (Morrison *et al.*, 1980 and Thomas *et al.*, 1991) are, in some cases, no longer appropriate.

Researchers and the farming community alike are exploring more extensive, low input systems of livestock production, which are environmentally sensitive and sustainable. It is not surprising therefore that a great deal of attention in recent years has focused on the role and potential of white clover. This has resulted in a great amount of published research on many diverse aspects of this plant. This in turn has highlighted the difficulty of collating and analysing all this material. However this has been addressed over the years with the publication of a number of reviews on various aspects of white clover, covering the period before fertiliser nitrogen attained its prominence until the recent resurgence of interest in low input systems.

The Monograph by Erith (1924), now regarded as a classical textbook on white clover, gave an account of its anatomy, physiology, morphology, growth and development and agricultural value.

Reviews by Martin (1960), Frame and Newbould (1984) and Laidlaw and Frame (1988) deal with the use of white clover in grassland. A British Grassland Society symposium (Lowe, 1969) on white clover, provided a forum for the presentation and discussion of then contemporary research on white clover with regard to Rhizobium symbiosis, breeding, association with grass, agronomy and place in production systems. The biology and agronomy of white clover were reviewed by Spedding and Diekmahns (1972), whereas the ecological niche of white clover was described in a series of articles Turkington and Harper (1979a,b,c,d), while competitive aspects of grass / legume associations were reviewed by Haynes (1980).

Many of the botanical and physiological aspects of white clover is presented in a textbook bearing the title "White Clover" edited by Baker and Williams (1987).

On a global scale, a literature review by Frame and Newbould (1986) gave an updated comprehensive account of the state of knowledge with regard to the agronomy of white clover in a north western Europe and New Zealand context. Similar reviews on white clover in North America were published by Carlson *et al.* (1985) and Gibson and Cope (1985) while Brock *et al.* (1989) reviewed fifty years of white clover research in New Zealand.

The relative merits of the parameters used to characterise the state, dynamics and productivity of the grass / white clover sward and the relevant field and laboratory procedures appropriate for this type of work were reviewed by Brown (1954), t'Mannetje *et al.* (1978 a), Hodgson *et al.* (1981) Meijs *et al.* (1982) and Leaver (1982). The Hodgson *et al.*, "Sward Measurement Handbook" has been revised and updated recently, but not yet printed.

With due regard to the afore mentioned and many other extant publications it is proposed to limit this review to aspects of growth and development, agronomy and management of grass / white clover associations immediately pertinent to the scope of the investigations reported in this thesis.

White clover has long been recognised as one of the most significant species currently in use in temperate agriculture (Brougham *et al.*, 1978), the most important pasture legume in temperate agriculture (Frame and Newbould, 1986) and among the foremost pasture plants in the world (Erith, 1924). This is due to its wide climatic range, habitat tolerance, remarkable colonising ability, the high nutritional quality and digestibility of its herbage, the significant contribution it makes to the nitrogen economy of grass / white clover pastures by fixation of atmospheric nitrogen, especially in the absence of fertiliser nitrogen, and its value in rotations when white clover-rich leys are ploughed in.

Overall yields of herbage from grass / white clover swards receiving no applied nitrogen were shown to be equivalent to those from grass only swards receiving nitrogen fertiliser at levels ranging from 140 to 300 kg N / ha (Holmes and Aldrich, 1957, Chestnutt and Lowe, 1970, Reid, 1972, Reid, 1976, Dobson and Beaty, 1977, Morrison *et al.*, 1979, Ingram and Aldrich, 1981, Morrison, 1981 and Curll, 1982) or to 70% - 80% of a pure grass sward receiving 400 kg N / ha (Morrison *et al.*, 1983). The range of observed equivalences with regard to white clover and fertiliser nitrogen contributions was no doubt a function of a number of factors including site potential, sward white clover content and the suitability of conditions for rhizobial activity. However, the contribution of white clover in perennial ryegrass (*Lolium perenne L.*) / white clover swards has been regarded for many years as unreliable (Aldrich, 1972 and Wolton, 1972), mainly due to its seasonality and the effects of climate. Likewise, Frame and Newbould (1984) observed that the attainment and maintenance of optimum white clover proportions within the sward is very difficult to achieve particularly with regard to the alleged unpredictability and lack of reliability associated with white clover based systems, from year to year, a reason which has discouraged farmers from moving from fertiliser-nitrogen based systems to zero nitrogen grass / white clover based systems. In an attempt to maintain consistent production, fertiliser nitrogen has been used on grass / white clover swards, which in turn tended to nullify the white clover contribution to the sward nitrogen balance even further. Some have therefore come to regard the sole justification for the inclusion of white clover as its effect on quality of diet (Aldrich, 1972).

In defence of white clover-based systems, Lowe (1969b) and Morrison *et al.* (1983) suggested that while swards depending on clover are 20 to 30% less productive in early spring they were as productive in late season as swards receiving moderate inputs of N fertiliser. Despite accusations of unreliability, Garwood and Tyson (1979) concluded that a productive perennial ryegrass / white clover sward could be maintained with appropriate management on suitable soils, but Laidlaw and Frame (1988) pointed out that the optimum grazing system for grass / white clover swards was still not clearly defined and they explained that the unpredictability of white clover systems was due, at least in part, to the complex dynamics of the grass / white clover association not being, as yet, fully understood and that this was therefore an area of study worthy of priority effort by researchers.

1.2 GROWTH AND DEVELOPMENT

1.2.1 The principal perennial grass species

While the agronomic characteristics of temperate grass species or mixtures of grasses are outwith the remit of this review and the associated investigations described in this thesis, it is nevertheless helpful to have an understanding of their growth characteristics and response to defoliation when grown in monocultures or in mixtures with other grass species as a basis for examining their use as companions to white clover. The performance and value of perennial grass species is greatly influenced by their response to environmental parameters such as soil characteristics, in particular its water-holding capacity, climate, especially with regard to drought resistance, and management factors such as cutting frequency, height of cut and level of fertiliser nitrogen application, if any (Aldrich, 1977). The botanical, physiological, morphological and agronomic characteristics of these grasses have been outlined and reviewed in many popular and scientific texts such as Spedding and Diekmahns (1972), Aldrich (1972), Robson *et al.*(1989) and Frame (1992) and may be summarised as follows.

Perennial ryegrass characteristics

* Growth commences early in the spring, although later than Italian ryegrass.
* Peak growth rate occurs during May, with poor mid season growth during June (especially in dry summers) and good late summer and autumn growth producing a smaller peak in July to mid August.
* A diverse species showing a wide range of seasonal growth characteristics in terms of maturity and heading date and of growth habit.
* A high yielding grass with the ability to produce higher yields of DOM than any other common temperate grass.
* It responds well to high fertility conditions and especially to nitrogen fertiliser applications.
* It is quick to establish, has good tillering capacity and is aggressive making it an excellent competitor.
* It is both highly digestible and acceptable to ruminants.
* Persistent under good management.
* Persists under frequent mowing provided there is adequate moisture and plant nutrients.

Timothy characteristics

* Generally later than perennial ryegrass with poor mid summer growth and good late summer grazing.
* High yielding and capable of producing the largest single crop of the common temperate grasses - this however would be the bulk of the annual yield.
* Its recovery after defoliation is slow.
* The most palatable of the common temperate grasses rendering it susceptible to selective grazing in mixed swards, which combined with its slow recovery after grazing make it a poor competitor.
* It is less digestible than perennial ryegrass at the equivalent stage of maturity although more digestible than cocksfoot. The point of rapid decline in digestibility commences about two weeks before 50% ear emergence and thus physiologically earlier than in perennial ryegrass.

* It is persistent under infrequent cutting although less so with frequent cutting.
* Winter hardy.

Meadow fescue characteristics

* Moderate yielder (even on low fertility soils with no fertiliser nitrogen or on wet, occasionally flooded soils, where it could outyield perennial ryegrass).
* Does not give as high a yield response to fertiliser nitrogen as perennial ryegrass. timothy or cocksfoot.
* Yield and response to fertiliser nitrogen are both reduced by frequent cutting.
* Similar digestibility to perennial ryegrass.
* Highly acceptable to grazing stock when kept leafy.
* Not aggressive.
* Lacks persistency under intensive stocking.

Cocksfoot characteristics

* Deep rooting growth habit allows rapid mid-summer and autumn growth even in drought conditions and makes the grass appropriate to light sandy soils and low rainfall areas.
* Generally low to moderate yielding.
* About 5 units of digestibility lower than perennial ryegrass at the same growth stage.
* Becomes course and unpalatable with lax grazing and in mixtures with other grasses is often rejected so that in time it dominates the sward.
* Tends to lose vigour under hard continuous grazing and thrives best under rotational grazing.

Garwood (1969) showed the mid summer dip in tiller production to be greatest with perennial ryegrass and timothy and least with cocksfoot. The relative yields and seasonal growth characteristics are demonstrated for frequent and less frequent cutting regimes in table 1.1.

Table 1.1 Seasonal DM yield and "D-value" of perennial grasses (first harvest year).
9 cut - 425 kg N/ha; 4 cut - 300 kg N/ha
(data metricated and derived from Aldrich, 1972)

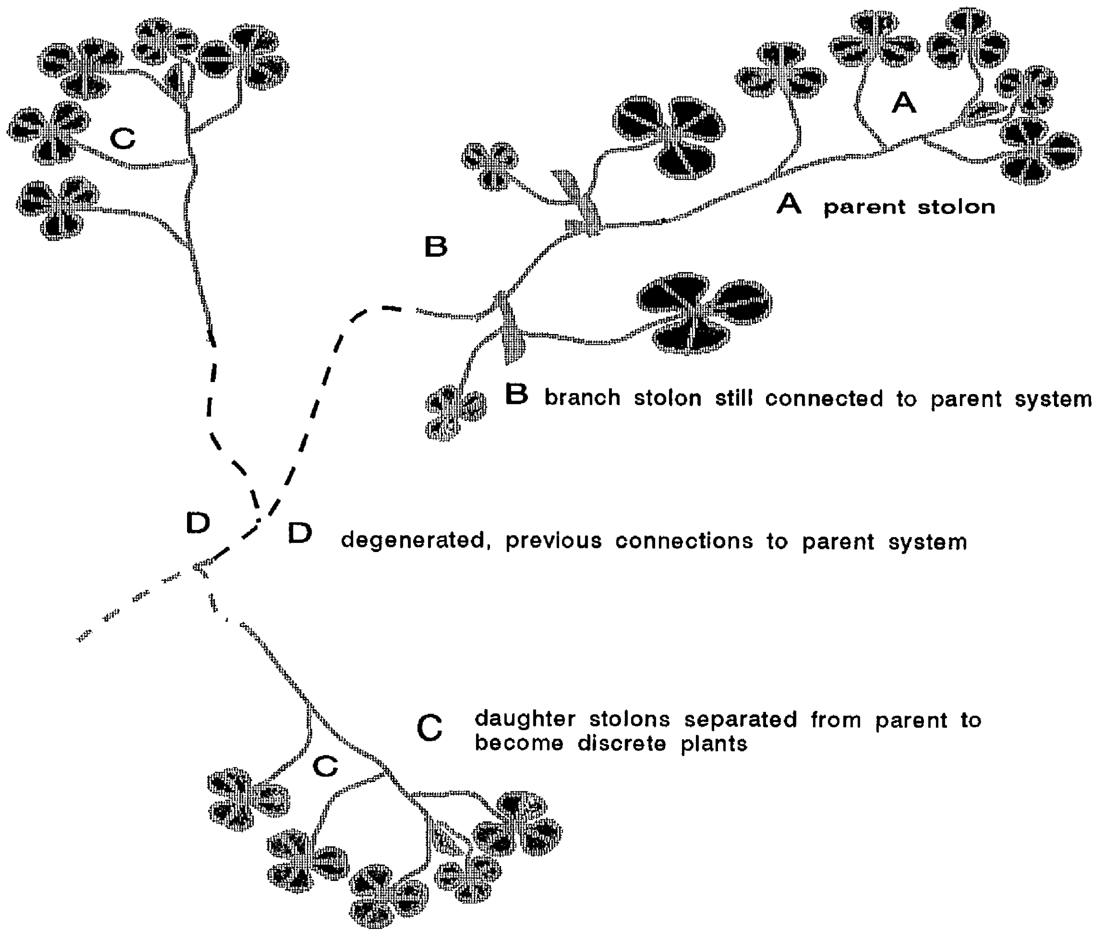
	Dry matter yield (kg/ha) - 9 cuts						4 cut DM Total (kg/ha)
	Spring	Summer		Autumn	Total	"D"	
		early	late				
Perennial ryegrass	2242	3699	3138	1569	10648	68.1	13898
Meadow fescue	1793	3699	3250	1345	9975	68.0	13001
Cocksfoot	1457	3811	3587	1345	10199	63.5	12105
Timothy	1905	3250	3026	1009	9078	68.0	12105

1.2.2 White clover

1.2.2.1 White clover stolon development

Erith (1924), Sanderson (1966), Spedding and Diekmahns (1972), Chapman (1983) Frame and Newbould (1986), Robson *et al.* (1989) and Hoglind (1992), described white clover seedling growth and development as follows. A short primary stem with 5-8 nodes and its extensively branched tap root develop. Internodes on this primary stem do not elongate so that leaves become crowded with primary stolons developing in the leaf axils to form a rosette. Secondary and tertiary branch stolons then develop, internodes elongate and each node has the potential to produce adventitious roots if it makes contact with moist soil. Usually within eighteen months or less, the proximal ends of the stolons degenerate and individual daughter stolons take on an independent existence and are therefore recognised as discrete and separate white clover plants (figure 1.1).

Figure 1.1 development of white clover stolon mat and formation of discrete plants (Spedding and Diekmahns,1972 and Chapman, 1983)

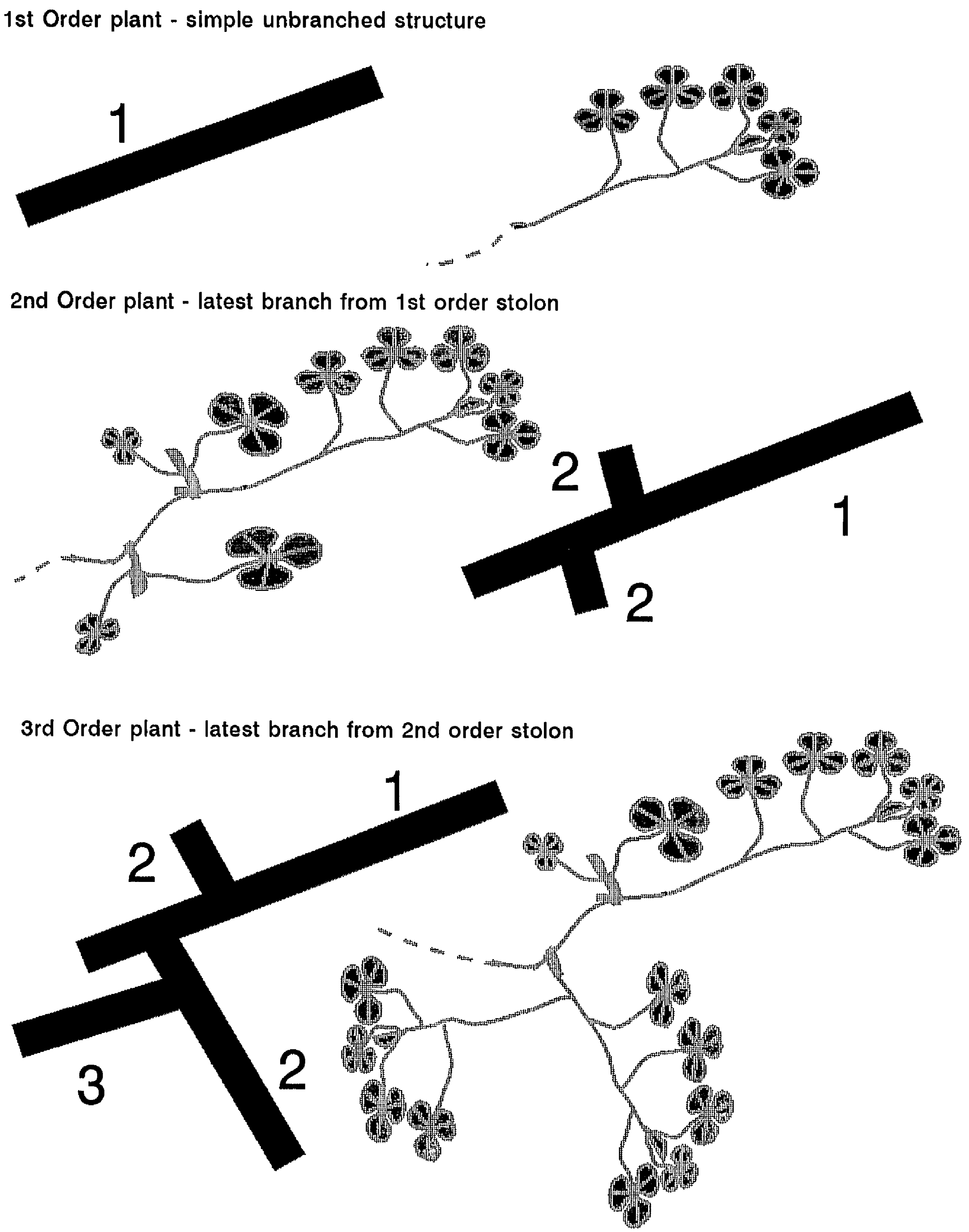


Brock *et al.*(1988), in their work on white clover stolons classified these independent white clover "plants" in terms of morphological age based on branching complexity. This was adopted in principle by Fothergill *et al.*(1990) and Fothergill (1992) who outlined the technique of classification of white clover plants into plant orders according to their degree of complexity as follows (personal communication):

1st order plant	-	simplest unbranched structure
2nd order plant	-	latest branch arising from a 1st order stolon (single or multiple)
3rd order plant	-	latest branch arising from a second order stolon, and so on.

Using this technique he quoted typical figures of around 5000 plants / m^2.

Figure 1.2 Classification of white clover stolons into plant orders (Brock *et al.*, 1988, Fothergill *et al.*, 1990, Fothergill, 1992 and Fothergill and Davies, 1993)



Seasonal changes in white clover stolon growth were outlined by Beinhart (1963) as follows:

1. Rapid growth commences in late March with primary stolons radiating outwards from the plants centre over a period of 4-6 weeks. These primary stolons accounted for nearly all the leaf area produced.
2. Branches, or secondary stolons, from the primaries are produced rapidly from mid - April through May. Secondary leaf area will approximately equal primary by the end of May and became increasingly dominant during the summer. Branching percentages of primary nodes produced in July and August are relatively low and most of the leaf area in this period comes from April, May and June branches.
3. In September, many tertiary meristems become active and contribute a large portion of the total leaf area by the end of that month. Dense foliage produced by tertiary meristems and secondary stolons is present by mid November.

In their work Fothergill and Davies (1993) confirmed that of Brock *et al.* (1988) and showed strong seasonal shifts in the distribution between plant orders with the proportion of first order plants increasing from January to June (in the UK), probably due to larger plants breaking up, with a corresponding reduction in second and third order plants over the same period. They also noticed that the proportion of first order plants increased from year to year. Both groups of workers recognised that lower order plants with their small size and simple branching structure could be vulnerable to stress (environmental and managerial) which may be involved in sudden unexplained declines of white clover in swards (Wright, 1975, Stewart and Haycock 1983, Frame and Newbould, 1984; 1986 and Hoglund, 1985). Fothergill and Davies suggest that large numbers of lower order plants may be used to give warning of any big drop in sward clover content. This agrees with the work of Chapman *et al.* (1989) who found that young branches were vulnerable to the removal of parent stolon leaves as the former export more "carbon" whereas the latter have a more stable "carbon" economy based on internal supply. They also concluded that a highly branched plant should be more stable than a weakly branched plant as there is greater scope for integrating the effects of environmental stress, such as shading or defoliation, across the whole plant.

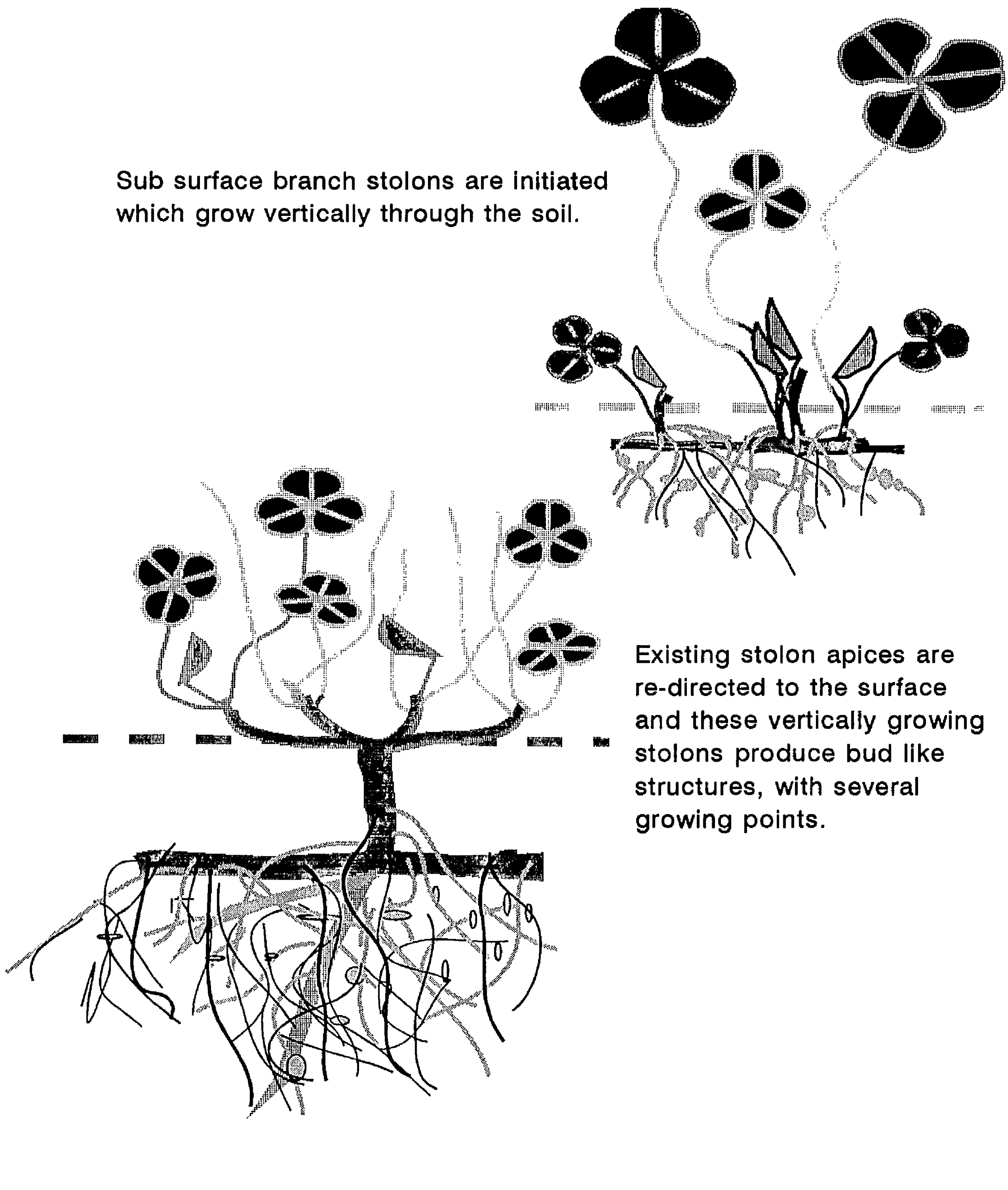
The mechanism of branching was examined by Laidlaw (1991) who suggested the involvement of phytochrome in the initiation of branch bud development and linked increased bud development from nodes with an increasing red : far red ratio. Thus shading or darkness at the base of the canopy inhibit branching and induce stolon and petiole elongation. This has possible implications in terms of the effects of shading, defoliation interval and severity, time of year and companion grass on stolon branching.

The causes and effects of white clover stolon spacial position within the sward, and particularly of buried stolon were examined by Hay (1983) and Hay *et al.* (1983) who recognised and described three vertical classes of stolon as aerial, surface and buried. They recorded that buried stolon formed a large percentage of the total stolon weight and increased from a minimum in autumn (30% - 40%) to a maximum in the spring (85% - 99%). They concluded that earthworm castings rather than stock trampling was the main factor responsible for stolon burial. Drought reduced the amount of stolon and modified its distribution in favour of buried stolon (Hay and Chapman, 1984). Hay (1985) explained that white clover undergoes an annual cycle with the burial of stolons in winter, re-emergence of growing points in the spring and surface stolon development over summer.

From their review, Frame and Newbould (1986) concluded that detailed investigations into stolon distribution strata were warranted in grazing studies on grass / white clover swards in the future because of its importance to white clover persistence.

The effect of stolon burial on the growth of white clover was described by Hay (1983) as follows. Sub-surface branch stolons are initiated which grow vertically through the soil; existing stolon apices are re-directed to the surface; and these vertically growing stolons produce bud-like structures, with several growing points.

Figure 1.3 The effects of stolon burial on subsequent stolon growth (Hay, 1983)



In a factorial pot experiment, Grant *et al.* (1991) examined some of the stolon burial and defoliation elements of grazing and found that:

Burial of stolons in the absence of defoliation:

* had no effect on stolon extension, leaf appearance, or the concentration of water soluble carbohydrates in the stolons;
* increased the number of axillary buds developing on new surface growing points of primary stolons;
* decreased the number of axillary buds developing on new surface growing points of branch stolons.

Defoliation on the other hand caused:

* substantial reductions in the concentration of water soluble carbohydrates in stolons and stolon extension growth;
* a reduction in the number of axillary buds developing;
* a reduction in the proportion of buds which were floral;
* a small effect in reducing leaf appearance.

The combination of stolon burial and defoliation resulted in:

* the death of secondary stolons (42% of all secondary stolons had died in six weeks);
* a reduction in stolon extension, leaf appearance and numbers of axillary buds developing on secondary stolons;
* an increase in number of axillary buds developing on primary stolons due to more buds developing on the resurfaced stolon tips, but this increase was not sufficient to compensate for the reduced growth, and death of secondary stolons.

The survival and growth of branched stolons was linked with root development at the node of origin by Chapman (1983) who argued that while initially, daughter branches rely on parent stolons for assimilates, their survival is often dependent on their own water and nutrient supply. Marshall and James (1988) found that stolon growth and development was influenced by plant density, variety and year. At low plant densities both large and small leaved varieties of white clover produced longer primary stolons than at higher densities.

Newton *et al.*(1992) developed a technique to test the viability of axillary buds. Axillary buds were classified into viability categories, data collated and a flow chart on the fate of axillary buds produced.

The effect of applied nitrogen fertiliser was investigated by Wilman and Asiegbu (1982b) who found that stolon length was less adversely affected by applied fertiliser nitrogen in the medium large than in the small leaved varieties. The small leaved varieties had thinner stolons than medium large leaved varieties but about twice the stolon length when no nitrogen fertiliser was applied, and a relatively high proportion of leaves which escaped defoliation.

Collins *et al.*(1991) highlighted the importance of maintaining a network of live stolon over the winter as annual clover yield was shown to be correlated with the amount of stolon present (expressed in weight or length) in March / April. The amount of stolon present in late autumn and early winter together with the effect of winter damage had a direct effect on stolon survival through the winter and therefore on yield the following year.

1.2.2.2 White clover leaves

Leaves are borne alternately on long petioles with petiole length being related to degree of shading, while leaf size and shape are a function of variety and position on stolon. White clover leaf appearance rates are slower in winter and greater later in spring than grasses (Chapman *et al.*, 1983). Brougham (1962) followed changes in the growth and development of the leaf canopy of undisturbed white clover and recorded the heights from the ground and quantity of clover herbage at the point of 95% light interception. In both cases the lowest values occurred in winter and the highest in late spring. He also deduced that the limits of growth are determined by temperature and water supply.

Spring growth in clover commences with an increase in leaf number per apex in March whereas an increase in leaf size was not observed until more than a month later in April (Haycock, 1981). The associated increase in leaf dry weight was maintained right through till July. Haycock (1984) working on pure stands of clover observed that during the summer the density of growing points decreased while the number of leaves per growing point and mean dry weight per leaf increased. The principal component of yield, mean dry weight per leaf, increased later than number of leaves per growing point. Stolons did not show the same cyclical pattern. However it is worthy of note here that the monoculture was established in August, with measurements taken from October to the following October. Davies and Evans (1982) found that during the winter, the rates of formation and loss of leaves were approximately equal so that there was no net increase in weight until the latter part of March. The most important factor was the difference in weight between the new leaf plus petiole unit and the weight of the unit it replaced. Leaf death rates, leaf longevity and tiller and stolon death rates were compared by Chapman *et al.* (1984), under rotational grazing and set stocking. Leaf longevity, leaf death rates and number of live leaves per tiller or stolon were found to be largely unaffected by grazing management. Leaf longevity was least in spring and summer, when death rates were fastest and greatest in winter when death rates were slowest .

Garwood and Tyson (1979) studied changes in the productivity of a perennial ryegrass / white clover sward over 24 years. There was a yield decline from the first year (9.6 tonnes dry matter / ha) to the eighth year (4.6 tonnes dry matter / ha). Thereafter yields recovered and averaged 8 tonnes dry matter / ha. They suggested that the recovery was due to increased nitrogen availability from mineralisation consequent on recycling of animal returns.

White clover shows great diversity with regard to growth habit and morphology. Hawkins (1960) categorised white clover according to leaf size with small leaved white clovers (leaflets 10-20 mm x 12-14 mm) and the remainder as large leaved types (leaflets < 50 mm x 40 mm) with long petioles. This was subsequently developed into the current classification which recognises four classes of white clover. These are very large-leaved, large-leaved, medium-leaved and small-leaved. The divisions between these groups are purely arbitrary, and are based on the unit size (length in mm x breadth in mm) of the terminal leaflet of a variety and its relationship to standard varieties (NIAB/SAC/DANI, 1991). This classification system is useful, although care must be taken with varieties which lie close to the leaf size limits of any category. It must also be remembered that the allocation of white clovers to specific leaf size categories is based on data collected from spaced plants which include standard varieties for comparison, conducted under common cutting management conditions. Under different management, such as hard sheep grazing, the leaf size would be reduced, or in competition with long grass, petiole length and leaf size may be modified.

1.3 GRASS / WHITE CLOVER ASSOCIATIONS

1.3.1 White clover

1.3.1.1 White clover leaf size

With regard to herbage production, Widdup and Turner (1983), growing white clover in monocultures and mixtures, found that clover production was least from small leaved clovers, intermediate from medium leaved clovers and greatest from large leaved clovers. Likewise, Frame and Boyd (1987) using small, medium and large leaved white clover cultivars in association with perennial ryegrass showed that under cutting, large leaved white clover varieties were more productive than the small or medium leaved varieties. However, under continuous stocking with ewes with twin lambs, Swift and Vipond (1993) found that small leaved clovers were more persistent and, in terms of livestock output, more productive than larger leaved types.

Widdup and Turner (1983) also found that companion grass production was greatest with small leaved clovers and least with larger leaved types. This compensatory effect resulted in pasture mixtures producing similar total herbage. This confirmed the findings of Ingram and Aldrich (1981), who showed that in general, high dry matter yield of white clover was associated with large leaf size, though not invariably so and also commented that high yielding clovers tend to depress companion grass yield more than small leaved types.

This general trend was not always observed, and frequency of defoliation was shown to influence the relative yielding ability of different types of white clover. Rhodes and Ngah (1983) recorded that in general, long petioled, large leaved varieties tended to have higher yielding capacity under infrequent cutting whereas smaller leaved varieties were often more productive, though not universally so, under frequent cutting. Wilman and Asiegbu (1982b) supported the view that medium large leaved varieties of white clover could, with advantage, be defoliated rather less frequently than small leaved varieties. Spedding and Diekmahns (1972) stated that small leaved white clovers were adapted to withstand frequent defoliation, whereas the two intermediate groups required more lenient harvesting.

Spedding and Diekmahns (1972) also concluded that small leaved white clovers had the distinguishing ability to withstand frequent and severe defoliation. This was verified by the work of Evans and Williams (1987) who compared cutting, continuous stocking by sheep and rotational grazing by sheep. They found that larger leaved varieties of white clover were favoured by the cutting regime and small and medium small leaved varieties were more suitable for continuous stocking whereas under rotational grazing, leaf size made little difference. While noting that large leaved varieties were highest yielding under cutting (5-6 cuts / year) and the small leaved varieties the lowest, Swift *et al.* (1992a) found that the rankings were reversed under continuous stocking by sheep and medium leaved varieties behaved like large leaved varieties. Under grazing small leaved varieties had 2-3 times the ground cover of the larger leaved types whereas there was little difference in cover between white clover types under cutting. They also concluded that the performance of white clover varieties under cutting should not be extrapolated to continuous sheep grazing. In New Zealand, Korte and Parsons (1984) examined large leaved clover under hard grazing and concluded, that although white clover became more prostrate and smaller leaved under hard grazing, the adaptation was insufficient to prevent most photosynthetic tissue being grazed.

With regard to a possible interaction between clover leaf size and fertiliser applications, Aldrich (1969) observed that all varieties showed some reduction in white clover yield, when nitrogen was applied, but that this reduction was least with large leaved clovers and greatest with small leaved clovers and non-persistent clovers. On the other hand, Frame and Boyd (1987) found no interaction between clover leaf size and fertiliser N applications and noted that high yielding varieties maintained their superiority over poorer varieties regardless of N application rate.

Investigating canopy structure using large and small leaved white clovers in association with perennial ryegrass or tall fescue (*Festuca arundinacea* Schreb.), Woledge *et al.* (1992a) found both clover types in the topmost layer receiving the best light even when the sward surface height reached 40 cm in early June. Except in early spring both clover types had a greater proportion of their leaf area near the top of the canopy than did the companion grasses. In a grazing situation, Milne *et al.* (1982) found a greater proportion of white clover in the grazed horizon than in the sward as a whole, thus, the position of white clover leaves high in the canopy contributes to some passive selective harvesting by mower or grazing animal. Wilman and Shrestha (1985) observed that perennial ryegrass adapted to a taller canopy by increasing the length of its leaf blades much more than it increased the length of its leaf sheaths, and by increasing the length of its blades proportionately more than their width. White clover, on the other hand, adapted by increasing the length of its petioles much more than it increased the length of its leaflets.

Persistence of white clover varieties appears to be related to petiole length and defoliation management. Comparing long petioled white clover, Blanca, with short petioled S100, under three cut and six cut regimes McEwen and Johnson (1984) demonstrated the superiority of Blanca in terms of persistence, albeit, the effects of the grazing animal were not included. Davies (1970), Munro *et al.* (1975), Baines *et al.*(1983) and Frame and Newbould (1986) however, stated that wild white clover types, which are strongly stoloniferous, have potentially better persistence than less stoloniferous large leaved types and certainly, Swift and Vipond (1993) found that small leaved white clovers were significantly more productive and persistent than large leaved types under continuous stocking by sheep. This trend was confirmed by the work of Charlton (1984), Charlton and Sedcole (1985) and Caradus (1989) who found that medium leaved Grasslands Huia did not perform well in hill country particularly under set stocked sheep grazing, (hence the development of Grasslands Tahora - a small leaved variety). Williams *et al.* (1982) found smaller leaved varieties were superior in this situation. Thomas (1984) showed that during drought situations, the leaves of small leaved white clovers became so small that they almost avoided defoliation completely and that this afforded them a competitive advantage and aided persistence.

1.3.1.2 White clover persistence

Camlin (1981) examined ten cultivars of perennial ryegrass separately associated with each of three white clover varieties taken from early, intermediate and late cultivars of ryegrass and small, medium and large leaved cultivars of white clover respectively. He found evidence to suggest that compatibility of ryegrass cultivars with clover was inversely related to ryegrass persistence. Non-persistent ryegrass cultivars consistently produced lower grass yields than the more persistent cultivars and consequently permitted greater clover contribution. However, it was also noted that in the longer term, the tendency for the production of one species to increase in response to the decline in the production of the other species, resulted in little change in total herbage production. Persistence in white clover then, is influenced by leaf size, or clover type but also by management. Korte and Parsons (1984) found that white clover was more persistent under rotational grazing by sheep than under continuous stocking by sheep. Sprague (1952) and Caradus (1989) concluded that white clover persistence was also affected by diseases, pests, deficiencies and toxicities of nutrients, and climatic factors.

Flowering and the associated seed production have also been shown to influence the persistence of white clover. Knight (1953) and Frame and Newbould (1986) explain that since each inflorescence produced eliminates the potential of a stolon bud to proliferate, profuse flowering is detrimental to plant persistence. Conversely, if seed was set and shed, the longevity of the white clover stand was assisted from subsequent germination of buried seed.

1.3.2 Compatibility / competition with white clover

1.3.2.1 Perennial grass species

Davies (1989) commented that ryegrass and white clover show differences in their growth and survival strategies which result in different reactions to season and management. White clover growing points increase in late summer rather than later and probably to a greater degree than tiller numbers. Numbers of tillers and growing points both declined over the winter, but sharp decreases in growing points can occur at almost any time of year unaccompanied by similar reductions in tiller numbers. She also suggested that this decline could be due to a number of reasons, such as, dry weather, stolon burial, trampling or slug damage.

Chestnutt and Lowe, 1970, reviewing results from twenty sources concluded that perennial ryegrass and meadow fescue were the most compatible with white clover, cocksfoot the least and timothy intermediate. With regard to the compatibility of timothy with white clover they reject the results of Hughes (1951), Hunt (1960), Martin (1960), Reid (1961) and Bland (1968) which indicated that levels of white clover were higher with timothy than with perennial ryegrass. Lex and Simon (1991) described timothy as a tolerant species which allowed white clover proportions of up to 30% and placed perennial ryegrass as intermediate between Timothy and cocksfoot which they also found to depress white clover strongly.

Cowling and Lockyer (1965) and the review by Spedding and Diekmahns (1972) noted that meadow fescue was the most compatible; perennial ryegrass was initially more competitive owing to its rapid early growth, but subsequently allowed a similar amount of white clover to grow in association. Conversely, clover established well with timothy, which was initially slow to develop, but which became more competitive in later years. Cocksfoot has been consistently recorded as highly competitive to white clover.

With regard to annual dry matter yields from white clover / grass species associations, Lex and Simon (1991) found the cocksfoot / white clover mixture highest , followed by timothy with perennial ryegrass lowest. However such results depend on the relative yielding abilities of the grass varieties chosen. In mixtures of perennial ryegrass and timothy without white clover, Chestnutt *et al.* (1980) and Chestnutt (1974) found that yield advantage may be related to seasonal changes in order of dominance of the two grass species but found also that the inclusion of clover changed the balance of grass species in favour of perennial ryegrass although no overall yield advantage was observed. Baines *et al (*1983), found cocksfoot was the most competitive grass while timothy and meadow fescue were the least competitive.

Within the perennial ryegrass species, the lower producing, less persistent varieties permitted the best performance by white clover (Cowling and Lockyer, 1965, Green and Corrall, 1965, Stewart *et al.* 1966, Wright and Faulkner, 1977 and Camlin, 1981).

Martin and Field (1984) showed that perennial ryegrass was more competitive than white clover and that its overall competitive ability increased with time. Root competition had the greatest effect initially (first harvest year), then similar effects from both roots and shoots were evident (second harvest year) and later (subsequent years) shoot competition was the greatest. Fertiliser nitrogen application aided the perennial ryegrass shoot competitive ability in later years. Mouat and Walker (1959) showed that applied fertiliser nitrogen increased the competitive advantage for nutrients of perennial ryegrass and cocksfoot in grass / clover associations.

Work based on the concept of co-adaptability, Rhodes (1982), Evans *et al.* (1985) and Rhodes *et al.* (1987) showed initial promise. This work noted that traditionally, grass and clover varieties have been bred separately with little regard to mutual compatibility. Collected material from natural grass and white clover populations co-existing in old pastures throughout Europe is therefore being used to develop compatible grass / white clover mixtures. While initial results show that any improved compatibility obtained using this procedure is not necessarily associated with high mixture yield, improved yields have been achieved from co-adapted lines and we await further developments in this area.

1.3.2.2 Complementary seasonal growth patterns

Spring

The delay in the commencement of spring growth by white clover (Williams, 1969) limited its competitiveness with a companion grass (Davies and Young, 1967, Spedding and Diekmahns, 1972 and Haycock and Ollerenshaw 1982). Davies (1992) related that white clover had a slower rate of growth than perennial ryegrass at temperatures below 10°C, but that its growth rate continued to increase up to 24°C, whereas the perennial ryegrass growth rate peaked at 15-20°C.

Mid summer / early autumn

Haynes (1980) observed that during mid summer and early autumn, when light and temperature are near optimal for white clover and when perennial ryegrass was showing post-reproductive or mid summer depression of growth, the white clover was able to spread through swards by stoloniferous growth. Brougham (1959) suggested that the dense white clover canopy and associated grass / clover competition for light, at that time of year, could be responsible for reduced grass yields the following year.

Late autumn, winter and early spring

Haynes (1980) also commented that the greater growth rates of perennial ryegrass under the low temperatures and light regimes of late autumn, winter and spring, which are more sub-optimal for white clover than for ryegrass, resulted in perennial ryegrass dominance during this period. Brougham (1959) observed that changes in the growth rate of perennial ryegrass during the winter and spring months were similar to those of total herbage, whereas at the onset of summer the perennial ryegrass growth rate decreased rapidly and by late summer and early autumn was negligible. The white clover component accounted for the overall growth rate during this period.

1.3.2.3 Diploid versus Tetraploid perennial ryegrass cultivars

Swift *et al.* (1990; 1993) and Vipond *et al.* (1989) reported on the same experiment. They compared a sward based on a late tetraploid variety of perennial ryegrass / small leaved white clover receiving no fertiliser nitrogen with swards based on a late diploid variety and a late tetraploid variety of perennial ryegrass, both grass swards receiving 150 kg fertiliser N per hectare annually. The sward surface heights were maintained between 4 cm and 6 cm until the end of June and were then allowed to rise to between 6 cm and 8 cm. White clover contents were observed to increase as the season progressed. Perennial ryegrass tiller densities were 23% higher in the diploid perennial ryegrass sward than in the tetraploid perennial ryegrass sward which had 43% more than the 10,000 tillers / m^2 of the tetraploid perennial ryegrass / white clover swards (Swift *et al.,* 1993). Unfortunately, their work did not include a diploid perennial ryegrass / white clover sward for comparison.

Collins (1985), Frame (1985a), and Davies (1985) observed that the white clover contribution and production tended to be greater with tetraploid rather than diploid perennial ryegrass as companion grasses. However, Frame (1985a) also commented that this trend is not marked. He went on to explain that recently developed tetraploid varieties of perennial ryegrass had a higher tillering capacity and formed a denser sward than the first tetraploid varieties released. He therefore concluded that there was probably little difference between diploid and tetraploid varieties. From farm sward comparisons, Swift and Vipond (1993), Swift *et al.* (1992 a,b & c) stated that tetraploid perennial ryegrass grass / white clover mixtures generally had higher clover contents than diploid perennial ryegrass mixtures.

Using a range of cutting treatments to simulate grazing and conservation managements combined with three N fertiliser rates, Lex and Simon (1991) found no significant differences in white clover content between diploid and tetraploid perennial ryegrass associations. The tetraploid perennial ryegrass / white clover swards did however give higher annual yield of dry matter. By inference therefore, the yield of clover was greatest from the tetraploid associations. This was borne out by the findings of Davies *et al.* (1991), who compared a very early flowering diploid perennial ryegrass with late flowering diploid and tetraploid perennial ryegrasses receiving 200 kg N / ha annually or in association with white clover receiving 75 kg N /ha annually. They found that the white clover contents were 15% for the very early diploid perennial ryegrass / white clover association, 13% for the late tetraploid perennial ryegrass / white clover association and 11% for the late diploid perennial ryegrass / white clover association. The above results suggest that when selecting varieties of perennial ryegrass for sheep grazing, the choice of diploid versus tetraploid is only one of the factors to be considered and that other variety characteristics along with the whole management strategy should be taken into account.

1.3.2.4 Maturity groups

The above findings of Davies *et al.* (1991) are somewhat in conflict with those of Frame (1985a) who concluded that with modern high yielding perennial ryegrass varieties ear emergence date did not have a marked effect on white clover performance. Lex and Simon (1991) found no significance in general between maturity group and white clover content although there was some indication of white clover levels in late perennial ryegrass associations falling in the second year. However late varieties of perennial ryegrass did produce the highest annual dry matter yields.

1.3.2.5 Strategic use of fertiliser nitrogen

The greater part of the annual production from perennial ryegrass is produced before mid June while white clover growth tends to be greatest from mid June onwards. The strategic use of applied nitrogen in early spring can enhance grass growth at its peak production with white clover providing a greater contribution to the herbage mass later in the season while utilising atmospheric nitrogen. This complementary use, therefore, of nitrogen by grass and white clover and their complementary growth patterns can result in higher annual yields of total herbage (Harris, 1968, Orr and Laidlaw, 1978 and Curll, 1982). Likewise, Frame (1987) found that total herbage DM was increased by spring application of fertiliser N (80 kg N / ha) but white clover production and content in the total herbage were reduced. However, the white clover which was depressed in the harvests immediately after N application, recovered during the season to amounts and contents in the total herbage to those given no spring N. With regard to nitrogen fertiliser applications (120 - 360 kg N /ha) applied repetitively over the season, Frame and Boyd (1987) concluded that these were incompatible with white clover persistence and production.

1.3.2.6 Target white clover contents

Martin (1960), Harris and Thomas (1973), Curll (1982) and Frame and Newbould (1986) all commented that a white clover contribution of 30% (or even as high as 50%) of the annual dry matter yield is desirable to optimise the benefits of nitrogen fixation and the superior nutritional quality of white clover. Harris and Thomas (1973) suggested that where white clover contributed more than 30% of the yield from grass / white clover mixtures, an equilibrium was attained in which seasonal changes and those related to nitrogen transfer, in grass : white clover ratios occurred without causing any marked effects of dominance and suppression by either species. This, however, requires verification.

1.4 EFFECTS OF CUTTING / GRAZING SYSTEM

LL Jones (1934) and Jones (1933) demonstrated conclusively that sward composition in terms of grass, clover and weed components and the balance of grass and clover in a sward could be altered by the intensity and timing of cutting and grazing managements while Harris and Thomas (1973) showed that strategic defoliations provided an efficient shift from grass to clover phase and that this should remain a fundamental consideration in grazing management decisions. More recently, the results of Evans *et al.* (1992) illustrated how alternating cutting, sheep grazing and cattle grazing managements was used to maintain optimum clover / grass balance.

The farmer then, is presented with a number of options with regard to the method of utilisation / defoliation of the grass / white clover sward. They include:

conservation cut	or	grazing
cattle grazing	or	sheep grazing
rotational grazing	or	continuous stocking

In this section, work on the effect of these alternative defoliation systems on grass / white clover associations will be discussed with due regard to frequency and severity of defoliation and the influence of treading and excreta. The strategic use or interchange of these options to manipulate sward composition will also be discussed.

1.4.1 Grazing versus cutting

Calder *et al.* (1970) found greater yields were produced on grazed than on clipped areas. With grass / white clover swards however, Sears (1951), Wolton *et al* (1970), Frame (1976) and Evans and Williams (1987) have shown that the clover content of mown swards is higher than that produced by grazing. This they attributed mainly to selective grazing and in particular to the removal of stolon material under grazing, but also to the return of excretal nitrogen which favoured grass growth. This was confirmed by Cuykendall and Marten (1968) who, in a similar context, concluded that high levels of N and K were necessary on cut plots to compensate for the effects of excreta. Taylor *et al.* (1960), Bryant and Blaser (1968) and Garwood *et al.* (1982), found that cattle grazing depressed white clover more than cutting. On the other hand, Briseno de la Hoz and Wilman, (1981) found that the effect of cattle grazing on white clover was similar to the effects of similar cutting treatments although it reduced the number of grass tillers and increased the proportion of bare ground compared with cutting or sheep grazing.

Using oesophageally fistulated sheep grazing a series of 24 swards over a range of clover contents (0-55%) Milne *et al.* (1982) found that the proportion of clover in the diet was greater than that in the sward. White clover leaf and stem were grazed to the same height. The proportion of white clover in the diet was greater than the proportion in the grazed horizon in week 3 of regrowth but not in weeks 1 and 2 and greater when the proportion of white clover in the grazed horizon was lower than 40%. These observations suggested selective grazing by sheep within the grazed horizons.

1.4.2 Cattle versus sheep grazing

Boswell (1976), showed that pasture production under grazing by sheep was greater than under grazing by cattle under similar intensive managements. It is generally accepted that smaller leaved white clover varieties are best suited to sheep grazing while larger leaved white clover varieties are best suited to cattle grazing. Monteath *et al.* (1977) found that the top 7.6 cm of soil was more compacted under cattle than under sheep grazing. However, Edmond (1970) found little difference between the effects of cattle and sheep treading on mixed grass / clover swards. The indications were however that sheep grazing tended to be the more harmful. When comparing the effects of cattle versus sheep grazing on grass / white clover swards, Briseno de la Hoz and Wilman (1981) observed that cattle grazing depressed white clover less than sheep grazing because sheep actively sought out clover in preference to grass whereas the cattle did not. This agreed with the re-evaluation by Ridout and Robson (1991) of the original work of Clark and Harris (1985) in which they examined the evidence for selection of white clover within mixed swards and swards with alternate strips of grass and white clover. The original conclusions suggested that there was no evidence for selective grazing in the mixed sward but good evidence of preferential grazing of white clover in the strip sward. This preferential grazing was observed to decline in swards with more than 50% white clover. The re-analysis however showed a 2:1 preference for white clover in the mixed sward compared with a 5:1 preference for white clover in the strip sward. The decreasing preference in the strip swards was not indicated although evidence to reinforce the suggestion that active selective grazing declines with white clover levels over 50% was found by Milne *et al.* (1982) and Curll *et al.* (1985a). This preferential (active) selection of white clover in grass / white clover swards confirmed work by Calder (1970) using timothy / white clover swards, who observed the same selective grazing by sheep when under both rotational and continuous stocking systems with sheep grazing more severely than cattle, defoliating the lamina portion of the plant thus leaving more petiole standing than the cattle. Evans *et al.* (1992) agreed that cattle grazing was less detrimental to white clover than sheep grazing and also observed cattle were not selective and removed less stolon. They also noted that with both cattle and sheep grazing, the larger the clover leaf size the greater was the loss in stolon, which in turn decreased persistency. Reviewing this topic, Frame and Newbould (1986) conclude that sheep graze more fastidiously than cattle and can readily select individual leaves and stems. Cattle tend to prehend bunches of foliage and will graze longer material.

These differences in both the mechanics of grazing and grazing behaviour between cattle and sheep suggest that the strategic inter-change of cattle and sheep grazing could be used as a management tool to adjust the relative proportions of grass and white clover within a sward. A change from sheep to cattle grazing was found by Boswell (1976) to cause a rapid deterioration in pasture production, while the change in grazing from cattle to sheep brought a slow improvement in pasture production. This was in keeping with the findings of Boswell (1976) who found that a change from sheep to cattle grazing caused a rapid deterioration of the ryegrass component of mixed grass swards. However, Monteath *et al.* (1977) showed that in summer, the change from sheep to cattle grazing brought about an increase in the production of the white clover component of the sward.

Comparing grass / white clover swards, whether continuously stocked or rotationally grazed by sheep, with similar swards rotationally grazed by cattle, Chapman (1983) observed that stolon elongation was greatest under cattle grazing whereas node appearance rates were unaffected by treatments. Hay *et al.* (1983) and Hay and Chapman (1984) also observed that white clover stolon weight per unit length were greater under cattle grazing than sheep grazing. A large reduction in the amount of white clover stolon, shorter internodes, petioles and leaflets, and thinner stolon closer to the ground were found in response to sheep grazing by Briseno de la Hoz and Wilman,(1981). A possible explanation suggested by Clark *et al.* (1984) was that severe grazing by sheep involved some stolon grazing and therefore the removal of terminal apices, which in turn, gave stolons less chance to assimilate reserves so that exploration of territory was curtailed. More recent work by Evans *et al.*(1992) confirmed that less white clover stolon is removed by cattle than by sheep. They also observed however, that with both cattle and sheep, a greater loss of stolons with larger leaved white clover varieties than with smaller leaved which in turn decreased the persistency of the former.

1.4.3 Rotational versus continuous stocking

Johnson *et al.* (1990) concluded that good lamb performance was achieved under both systems, although rotational grazing was superior and also appeared to favour white clover growth. Parsons *et al.* (1984) showed that there were changes in the structure and physiology of continuously stocked perennial ryegrass swards when released from grazing. The continuously stocked swards comprised a large population of small tillers with associated low photosynthetic rate due to their low grass leaf area index. Once rested, the LAI increased, and tiller numbers decreased. Laidlaw and McBratney (1983) using sheep to graze perennial ryegrass / white clover swards and Calder (1970) using timothy / white clover swards showed that continuous stocking resulted in less white clover than rotational grazing. This agreed with the work of Newton *et al.* (1985) who had grazing ewes and lambs on perennial ryegrass / white clover swards, and found that, at the same stocking rates, under rotational grazing, the white clover content increased from 19% to 43% from March to mid June, to 54% by October and 28% the following March, whereas under continuous stocking, white clover levels fell from 14% to 9% to 6% to 4% on the same dates.

Korte and Parsons (1984) explained that rotational grazing systems which permitted a period of clover canopy development and allowed for the accumulation of reserves could be expected to improve white clover persistence compared with an intensive continuous stocking system. With regard to swards continuously stocked by sheep, Jones and Davies, (1988) noted that stolons usually had a green leaf complement varying between zero and two leaves per growing point and that white clover stolons survived for long periods with only one leaf present at any one time. They suggested therefore that a balance must be struck between maintaining sufficient leaf to sustain high clover growth rates and the increased risk of older leaves dying before they can be harvested. Lambourne (1956), Robinson and Simpson (1975) and Marsh and Laidlaw (1978) suggested that an interaction existed between continuous and rotational management systems and stocking rate. Clover content was lowered by continuous stocking and high stocking rates whilst animal performance and intake were increased by lowering stocking rates, increasing clover contents and by adopting continuous stocking systems. Chapman *et al.* (1983) observed that rotational grazing in summer allowed some relief from defoliation so that leaf appearances were greater than under set stocking. This complemented the findings of Laidlaw and McBratney (1983), who showed that the adverse effect of high stocking rate on clover associated with continuous stocking can be partially alleviated by rotational grazing.

Laidlaw and Steen (1989) concluded that the contribution of clover to growth is considerably higher than its presence in herbage mass would suggest in continuously stocked swards.

1.4.4 Severity and frequency of defoliation

1.4.4.1 Cutting

Frequency - Many cutting studies have shown that total herbage production from grass / white clover swards generally increases as the interval between defoliation is lengthened (Frame and Newbould, 1986). Holliday and Wilman (1965), however, recorded that increasing the defoliation interval for a prolonged period reduced both the amount and proportion of white clover in the total herbage. Wolton *et al.* (1970) who examined a range of cutting methods and frequencies for grass / white clover swards found that cutting interval or stage of growth did not reduce the white clover yield in any of their treatments. This is therefore an area which needs clarification though it seems likely that the time of year at which the infrequent cut (or prolonged rest from defoliation) occurs with regard to the complementary seasonal growth patterns of perennial ryegrass and white clover may be a major factor. Frame and Paterson (1987) and Frame (1987) using an intermediate tetraploid perennial ryegrass with a very large leaved white clover concluded that grass / white clover swards were suitable for management systems which involved infrequent cutting for conservation since sward white clover content was not substantially reduced by long rest intervals.

Severity - The effects of cutting height and method of cutting, examined by Reid (1959, 1962, 1966, 1967 and 1968) and Reid and MacClusky (1960), showed that cutting to 25 mm of ground level gave greater dry matter yields of grass and white clover than cutting to within 50 - 63 mm of ground level - the increase in dry matter yield ranged from 39 - 49%. Appadurai and Holmes (1964) set out to test these results in the light of conflicting results from Roberts and Hunt (1936) and Brougham (1960) who had concluded that lax defoliation was preferable to close cutting. Results from their study concluded that cutting to within 25 mm of the ground level significantly increased herbage yield provided moisture supplies were adequate but did not affect clover. The increase in yield occurred mainly in the period March to June. More recent work by Frame and Boyd (1987) using perennial ryegrass / white clover swards, found that close cutting (40 mm from ground level) increased total herbage and white clover content by 16% and 31% respectively relative to less severe cutting (80mm). These cutting heights are not directly comparable with those of Reid (above) but confirm the general conclusion of his work that closer cutting enhances both total herbage yield and clover content. Reid (1962 and 1968) also showed that timothy / white clover swards benefitted from lower cutting for two years but thereafter the advantage declined. No significant difference was found between cutting heights with cocksfoot / white clover swards.

Selectivity - Comparing cutting with both rotational and continuous stocking with sheep as management systems for grass / white clover swards, Evans and Williams (1987) showed that clover yields were less under grazing than cutting. This was due mainly to the selective grazing and removal of stolon material which occurred under grazing. However, Woledge *et al.* (1992b) found that cutting reduced the proportion of white clover dry weight in a perennial ryegrass / white clover sward by up to a half. This demonstrated the preferential removal of clover by the passive selection by a mower, and not only as a result of grazing which may also include active selection.

1.4.4.2 Rotational grazing

Within a rotational grazing system, severity and frequency of defoliation are functions of the duration of the grazing period, the duration of the recovery period, the pre and post grazing herbage heights and the type of grazing animal.

Betts *et al.* (1978) showed that there was no significant difference between rest and recovery periods of 3, 4 or 5 weeks or in the choice of one or four day shifts under rotational grazing in terms of the amount of white clover present. Widdup and Turner (1983) however, achieved the best production from both ryegrass and white clover components of grazed mixed swards with longer intervals between grazings. This is supported by Wilman and Asiegbu (1982a) who noted that increasing the interval between harvests from 3 or 4 to 8 - 12 weeks, although of little practical significance, increased the yield of white clover and generally did not reduce the proportion of clover in total herbage. They recorded also (Wilman and Asiegbu, 1982b) that increasing the interval between defoliations increased the length and weight of stolon per unit area, stolon diameter, petiole length, weight per leaf and number of leaves as a proportion of those present in the sward, while, only slightly reducing the rate of leaf emergence. Davies (1992) explained that frequent defoliation resulted in plants with short petioles and small leaves. Stolon extension was much curtailed and die back of older parts of stolon was increased. Plants which are allowed to grow undisturbed for several weeks between defoliation produced long petioles, large leaves and robust stolons, although the stolon represented a smaller proportion of their dry weight. Brougham (1960) investigating the effects of frequent hard grazings on grass / white clover swards found that such grazings in the spring reduced immediate dry matter yields, but had no detrimental effect on plant survival and yields were enhanced on a subsequent return to lax grazing. Hard grazings during the summer resulted in the death of grass tillers although white clover did not suffer. Hard grazings in autumn reduced immediate dry matter yields but enhanced the yield of the grass component the following spring.

1.4.4.3 Continuous stocking

Within a continuous stocking situation, severity and frequency of defoliation are functions of grazing pressure and the type of grazing animal. In this context it must be remembered that continuous grazing does not equate to continuous defoliation and that an interval will inevitably elapse between successive defoliations. The interval between defoliations is to a large extent dependant on grazing pressure. This was demonstrated by Curll and Wilkins (1982a) who examined the effects of high and low stocking rates of sheep on the frequency, severity and nature of defoliation on the components of grass / white clover swards (table 1.2). This theme was developed by Clark *et al,* (1984) who showed that under continuous stocking by sheep, defoliation intervals were longest in the winter and shortest in the spring when both ewes and lambs were grazing.

Another aspect of the effect of grazing pressure on continuously stocked swards is that a greater proportion of white clover stolon is removed at higher stocking rates, as demonstrated (table 1.2), with a tripling of the percentage of white clover stolon that is removed at the higher stocking rate. Frame and Newbould (1986) explained that selectivity of grazing depended upon stocking density in relation to available herbage mass and sward growth rate.

Table 1.2 Severity and frequency of defoliation in grass / white clover swards with low and high stocking rates under continuous stocking.

Frequency and severity of defoliation	GRAZING PRESSURE			
	HIGH (55 sheep / ha)		LOW (25 sheep / ha)	
	Grass per tiller	Clover per plant	Grass per tiller	Clover per plant
Defoliation interval in days	4.8	4.2	9.3	7.7
Leaf removed	58%	51%	48%	42%
Stolon grazed		12%		4%

Data derived and tabulated from Curll and Wilkins (1982a)

Bland (1967) found that in perennial ryegrass / white clover swards, increasing the frequency of defoliation, increased the yield from the white clover component.

Davies *et al.* (1989) noted that increasing stocking rate over the range 25 - 55 yearling sheep per hectare reduced herbage accumulation by about 40%, whether or not nitrogen fertiliser was applied. Increasing the stocking rate increased the density of ryegrass tillers but reduced the density of white clover stolons and the white clover content of the swards. Applications of nitrogen fertiliser (200 kg N/ha/annum) increased herbage accumulation by about 20% but substantially reduced the clover content. This confirmed the findings of Curll and Wilkins (1985) who found that continuous stocking with sheep at high stocking rates reduced the content of white clover in mixed grass / white clover swards compared with relatively low stocking rates.

Laidlaw and McBratney (1983) showed that the white clover under high stocking rates had more growing points and eventually smaller leaves than at low stocking rates and had a lower white clover content than low stocking rates in the following spring. Leaves were particularly small under high stocking rates / continuous stocking - by sheep. This was confirmed in cutting experiments by Briseno de la Hoz and Wilman (1981) who found that by reducing the height of defoliation in perennial ryegrass / white clover swards from 8 to 4 cm above ground level, they, reduced the dimensions of white clover. Laidlaw and McBratney (1983) concluded therefore that continuously stocked sheep at high stocking rates can result in a reduction in leaf size with a corresponding loss of competitive ability which they found, was in part, alleviated by rotational grazing at similar high stocking rates.

A stable grass / white clover association was maintained, however, under conditions of set stocking at around 25 yearling sheep per hectare and at this stocking rate, which appeared to be about the biological optimum, there was no advantage in using nitrogen fertiliser (Curll *et al*, 1985a). They also showed (Curll *et al.*, 1985b) that under high stocking rates, the adverse effects of over-grazing and nitrogen fertiliser application on white clover contribution in one season were partially rectified by lower stocking rates and by withholding nitrogen fertiliser in the following season.

Korte (1982) comparing grass / white clover swards under hard and lax grazing recorded that rank stemmy herbage developed under lax grazing whereas dense leafy pasture developed under hard grazing. Leafy swards had a higher herbage accumulation rate and a higher tiller density than stemmy swards. Likewise, work by Gibb and Baker (1989) showed that hard grazing (30 mm grazing height) of perennial ryegrass / white clover swards with beef cattle encouraged higher tiller numbers and more stolon growing points to develop than more lax grazing (70 mm grazing height). Later in the season, if grazing height was allowed to increase then tiller numbers and number of stolon growth points were reduced.

It is now widely accepted that sward surface height (SSH) can be used effectively as a guide to the adjustment of grazing pressure under continuous stocking. Orr *et al.* (1990) suggested that a sward surface height close to 60 mm (as in grass only swards) leads to optimum performance in grass / white clover swards grazed using continuous stocking with sheep. Penning *et al.* (1991) however advised that the optimum sward surface height for continuously stocked swards, grazed by sheep, was between 30 mm and 60 mm.

While, in general, it is true that rotational grazing is preferable to continuous stocking with regard to the persistence and development of white clover, Grant and Barthram (1990) showed that in continuously stocked perennial ryegrass / white clover swards, the incorporation of appropriately timed rest periods from grazing followed by cutting (e.g. silage cuts) could provide a means of enhancing clover content and performance. In this regard, Curll and Wilkins (1985) examining the effect of taking conservation cuts from perennial ryegrass / white clover swards which were under high and low continuous stocking rates, showed that when these swards were rested , white clover stolon length, petiole length and leaflet diameter increased although leaf and node number per unit length of stolon decreased. At the same time, the tiller density of perennial ryegrass decreased although tiller length increased. They also noted that when the rested swards were returned to grazing, the reverse trends were observed for both the perennial ryegrass and white clover. At the high stocking rate, rest periods in mid season or later maintained the greatest clover content and marginally increased total net herbage accumulation. At the low stocking rate, the timing of the rest period had no significant effect on total net herbage accumulation or on clover content. They concluded that a combination of grazing and cutting is of benefit where stocking rate is high enough to threaten clover survival and limit sheep performance. They noted however that at such stocking rates, feed reserves are at a minimum throughout the grazing season and so opportunities for resting the sward are probably low.

Davies and Jones (1988) found that a short rest of two weeks from continuous stocking with ewes and lambs, in the second half of July, increased the percentage of clover in a ryegrass / white clover sward which had been maintained at a sward surface height of between 4 and 6 cm. The rate of white clover leaf production and growth point production increased during the rest. Grazing after the rest in July resulted in a sharp decrease in clover leaf weight and in the loss of growing points which had formed during and just after the rest period. The subsequent production of herbage dry matter was predominantly from the grass component.

Relaxation of intense defoliation by perhaps taking a conservation cut (Wolton *et al*, 1970; Wilman and Asiegbu, 1982b) or a switch from high to low stocking density (Curll, 1982) or a change from continuous sheep grazing to rotational grazing (Marsh and Laidlaw, 1978; Laidlaw and McBratney, 1983; Newton *et al.*, 1984) can result in increased above-ground parts of white clover and therefore an increase in vigour and production.

An investigation by Grant and Barthram (1991) of the effect of an early rest (6 weeks from 27 April) and a late rest (6 weeks from 8 June) on grass / white clover swards which had been under a simulated continuous stocking regime (weekly cutting to 3.5 cm), showed that in the three weeks after the rest, clover leaf appearance rates were increased by 40% and branching by 164% while grass leaf appearance rates were reduced by 50% compared with the unrested sward. Though the rate responses were transient, effects were still apparent in September. The clover content was significantly higher in the late rested treatment.

1.4.5 Winter grazing

The winter is often the time of year when white clover is most at risk. Woledge *et al.* (1990) found that losses from clover during the winter included plant parts especially leaf (60% - 90% of lamina weight). The climatic change from autumn to winter caused a greater decrease in the number of leaves per shoot and in area and weight of individual leaves in clover than in grass. Harris *et al.* (1983) recorded a loss in biomass of clover leaf, stolon length and stolon weight during the winter. The decline was greatest with swards which had previously been managed under infrequent cutting or fertiliser nitrogen regimes. Because of this typical decline (and sometimes severe loss of stolon) better winter hardiness is an aim of plant breeders (Collins *et al.*, 1991).

Examining grass / white clover swards during the winter, Brougham (1960) and Brougham (1970) found that frequent hard grazings during this period encouraged the growth of both grass and clover and this was reflected in higher dry matter yields after a change to less intensive grazing in the next season. Likewise Scott (1973) found that three winter defoliations provided higher winter yields, mid spring and total herbage yields (March - November) than less frequent defoliations. Work by Laidlaw and Stewart (1987) showed that hard grazing with sheep for a short period in November is a suitable means of obtaining and maintaining high clover contents in a rotationally grazed beef production system by increasing both growing point density and clover contents during subsequent years. These findings were confirmed by Laidlaw and Withers (1989) with simulated sheep grazing to 3 cm in November or April. The November cut plots produced the lower November to late May herbage masses, but conversely the higher growing point densities after February. Laidlaw *et al.* (1992) concluded that stolon growing point density can be increased by grazing or cutting during winter or spring. They also advised that in order for these new stolons to contribute to clover yield during the summer, they have to be maintained until then by ensuring that competition from grass is minimised by keeping the sward short in winter and spring and avoiding the burial of stolons during grazing by avoiding severe treading during wet soil conditions.

1.4.6 Spring grazing

In some of the earliest work on the management of grass / white clover swards, Jones (1933b) set out and successfully developed two contrasting swards, one became clover dominant and one became grass dominant. The former was grazed very closely in the spring while in the latter was the herbage was allowed to grow. He attributed the success of these two strategies to the weakening of the grass, by hard spring grazing, which allowed the white clover to compete successfully later in the season, on the one hand, and to the strengthening of the ungrazed grass at a time when clover growth was minimal, on the other, thus reducing the ability of white clover to compete later in the season with the stronger grass. His results have been confirmed by those of more recent experiments (Fisher and Parker, 1992) using cow grazing where the imposition of severe grazing in spring increased the number of white clover growing points, nodes and stolon length compared with lax grazing. However it has also been shown that perennial ryegrass is encouraged to tiller by hard grazing (Baker and Leaver, 1986 and Fisher and Parker, 1992) in the spring and is therefore potentially a better competitor. The success of white clover under hard spring grazing is more likely to be in response to the amount of light passing to the base of the sward and its positive effect on white clover stolon branching (Laidlaw and Withers, 1989).

1.4.7 Treading and excreta effects

Treading - Much of the early work on treading was conducted by Edmond and reviewed by Brown and Evans (1973) and concluded that all treading damages pasture irrespective of soil type, soil moisture level, plant species or kind of animal He also noted that cutting likewise caused similar damage due to machinery tracking. Edmond (1964), classified white clover as more susceptible to treading damage than perennial ryegrass but more resistant than timothy or cocksfoot. He also observed that white clover was more tolerant of treading when grown in mixtures with grass than in monoculture.

Curll and Wilkins (1982b and 1983) found that treading by sheep at a stocking rate of 25 sheep / ha increased soil compaction but had no significant overall effect on herbage growth and botanical composition. However, treading by double the number of grazing animals (50 sheep / ha) significantly reduced total herbage growth by 10%, plant root weight by 47% and the proportion of clover in the sward by 11%. They also concluded that, differences in sward performance between stocking rates were due more to the difference in defoliation intensity between these stocking rates, than to either treading or the return of excreta which agreed with previously published work (Curll, 1980) where it was observed that defoliation occurred three times more frequently than treading but recorded a 20% greater frequency of treading damage on clover than on grass.

Excreta - In the same experiment Curll and Wilkins (1983) examined the effect of excreted N on the sward components and on livestock production, at the same stocking rates. Their results are summarised in Table 1.3

Table 1.3 The effects of excreted N on sward components and production.

Effect of excreted N	STOCKING RATE	
	High 50 sheep / ha	Low 25 sheep / ha
Daily excretion of N (kg/ha)	1.3	1.1
Herbage growth increase due to N	53%	26%
Clover proportion reduction	21%	26%
Clover weight reduction	none	13%
Stolon length change	reduced	none
Sheep liveweight	increased	no effect

Data derived and tabulated from Curll and Wilkins (1983)

Work on the effects of dung and urine on swards has been reviewed by Wolton (1979) who observed that at low stocking rates, dung and urine are unlikely to effect sward composition except very locally. At moderate to high stocking rates, excreta increased productivity and showed a tendency to move the sward to perennial ryegrass dominance. At very high stocking rates both perennial ryegrass and white clover suffered as the perennial ryegrass itself became susceptible to damage. This confirmed the work of Wheeler (1958) who found that urine increased the proportion of grass and reduced the clover, whereas dung returned alone exerted little influence on sward composition. Wheeler (1958) also found that urine restricted the incursion of weed grasses. Marriott *et al.* (1987) found that urine reduced clover population density, stolon length and dry weight and initial nitrogen fixing activity, with little effect on number of grass tillers.

Rebuffo (1986), working on the effects of cattle dung and urine on perennial ryegrass / white clover swards found that dung had no effect on the density of perennial ryegrass tillers or white clover growing points, but that white clover stolons and leaves were larger adjacent to the dung pats than elsewhere, especially in summer. Cattle were found to graze preferentially where urine had been voided, probably as a result of increased herbage availability rather than active selection. Urine increased the total yield of herbage by 36% -41%, but also increased the proportion or perennial ryegrass. The white clover yield however, was reduced by 20%. Urine increased the density of ryegrass tillers and reduced the number of white clover growing points.

1.5 SUMMARY OF PRINCIPLE MANAGEMENT CONCLUSIONS

This review highlights the potential of grass / white clover swards in temperate agriculture and describes the considerable amount of research activity directed at the aspects of sward composition and utilisation management. Some of the major conclusions are listed below.

1. Perennial ryegrass is superior to other temperate perennial agricultural grasses, receiving optimum levels of fertiliser nitrogen, in terms of digestibility, yield and flexibility to different management regimes. This explains its dominance in UK agriculture.

2. Meadow fescue is superior to other perennial agricultural grasses in terms of compatibility with white clover, while cocksfoot is the least compatible. Researchers do not agree on the intermediate placings of timothy and perennial ryegrass.

3. Tetraploid perennial ryegrass is in general more compatible with white clover than diploid perennial ryegrass. However management imposed and other varietal characteristics, may in some cases make diploid perennial ryegrass the better choice.

4. Large leaved white clovers are best suited to infrequent cutting such as conservation cuts as long as the growth period is not too long.

5. Small leaved white clovers are better adapted to intensive grazing regimes.

6. Rotational grazing is preferable to continuous stocking for white clover for larger leaved cultivars. However vigourous white clover can be maintained under continuous stocking provided it is controlled and varietal choice is suitable.

7. Cattle grazing is largely non-selective and in many ways similar to a cutting management. Sheep grazing is selective with sheep actively selecting clover. This gives excellent animal performance but requires diligence on the part of the grassland manager to maintain clover levels in the sward.

8. Target sward surface heights for sheep under continuous stocking on grass / white clover swards range between 30 mm - 60 mm up (with possible benefit in terms of animal production, to be gained by allowing levels to rise to 60 mm - 80 mm from the end of June).

9. Grass / white clover swards continuously stocked and severely grazed by sheep benefit from a rest for a conservation cut, a change to rotational grazing or a change to cattle grazing.

10. A dynamic situation seems to develop within the grass / white clover sward so that when a grass species or variety is aggressive or densely tillering, the white clover content is reduced. Conversely, with open less aggressive swards the white clover contribution is greater. This compensatory effect is also displayed by the different seasonal growth patterns of grasses and white clover and their different responses to different grazing regimes. However the dynamics change with for example, increased fertiliser N application and changes in management.

1.6 AREAS OF STUDY WHICH REQUIRE FURTHER CLARIFICATION

The review has identified areas where there are deficiencies in our understanding of grass / white clover sward component and management interactions or where researchers have presented conflicting results. Some of these areas are listed below and form the basis of the rationale for the experimental work reported in the following chapters.

1. The effect of perennial ryegrass variety maturity characteristics and perennial ryegrass ploidy on the production and relative composition of a perennial ryegrass / white clover sward.

2. The effect and timing of a rest for a conservation cut on perennial ryegrass / white clover swards continuously stocked by sheep.

3. The effect of managing perennial ryegrass / white clover swards for both infrequent cutting and continuous stocking by sheep on clovers from each of the leaf size categories.

4. The effects of interactions between the variables in 1, 2 and 3 above.

5. The value and performance of modern varieties of perennial grass species other than perennial ryegrass as companions for white clover in a zero nitrogen fertiliser situation.

6. Cutting and grazing strategies for different perennial grass species / white clover swards.

A greater understanding of sward, climate, herbivore and management interactions is needed to aid the reliability of grass / white clover swards for white clover based farming systems.

CHAPTER 2

EXPERIMENT 1

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS:

1. SWARD ASPECTS

CHAPTER 2

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS: 1. SWARD ASPECTS

INTRODUCTION

For expediency with regard to economy of scale and resources, researchers involved in much of the early work, and to a lesser extent recent work on the effects of grazing on different grass / white clover swards, have resorted to cutting techniques to simulate the effect of grazing, with frequent cutting and less frequent cutting related to continuous and rotational grazing respectively (eg. Frame, 1985b and Frame and Paterson, 1987). Plots were subjected to a range of cutting frequencies and cutting heights to simulate rotational grazing and even continuous stocking by various classes of stock. These investigations, while suggestive, do not provide a sufficiently reliable basis for the prediction of sward performance under grazing (Calder *et al.*, 1970). Apart from the direct effect of defoliation, many such experiments took little account of the many and diverse effects of grazing, such as the effects of treading / poaching, "bite" size, shape and penetration, active selective grazing of white clover stolon in particular (Evans and Williams, 1987), defecation and urination with associated rejection of herbage and changes in growth habit of grasses and white clover. Generally, in these experiments, extra fertiliser was applied to mimic as closely as possible the nutrients that would have been available from the excreta of the grazing animal. In other cases it was essential to exclude the grazing animal from areas of the grazed sward, so that the individual animal effects of treading, dung or urine and selection could be examined in isolation. For example, specially designed exclosure cages have been used which allow grazing in the absence of defecation and treading. In most cases however the choice of simulated grazing experiments was made because of constraints of scale, and limited resources. While such experiments have contributed greatly to our understanding of the response of grass and clover to different defoliation strategies, they in no way substitute for trials using grazing animals.

Frame (1966) suggests that since a general relationship between actual and simulated grazing is unlikely to be established for all swards, it is profitable to seek relationships within certain classes of sward and treatment. He concludes that it is improbable that actual grazing techniques will replace simulated grazing techniques because of the resources needed. Frame (1986) encouraged more intensive effort into production and utilisation of grass / white clover swards, particularly under grazing conditions. Latterly there has been a general move in favour of grazing experiments but inevitably this has been associated with fewer treatments since the minimum size of plot is greatly increased. Another constraint on grazing experiments is that if specific swards types of known components have to be investigated, a period equivalent to at least one experimental year is needed to establish the swards, after the initial planning and before treatments can be applied. This delay leads to extra cost and loss of commercial production and the time scales involved often render such experiments unsuitable to the type of limited period (2-3 years) investigation normally undertaken by full time post graduate students. These factors have lead, in many cases, to the use of existing grass / white clover swards of uncertain history and composition, or a few carefully selected grass / white clover varieties, being adopted as being "typical" of the range of diversity within the species. To these swards, a limited number or management regimes have been imposed. In such trials, it is not certain that a change in any sward component such as a different maturity group, or ploidy in the case of perennial ryegrass, or a different leaf size of white clover, or in grazing severity, or in the type of grazing animal or even in the timing of the imposition of a rest from continuous stocking might not have elicited a different outcome.

Work has been done on perennial ryegrass variety maturity group and its relevance to the performance and management of perennial ryegrass / white clover swards. Nevertheless some of this work was inconclusive (Frame, 1985a and Lex and Simon, 1991) and further clarification is needed. Likewise experiments have been conducted on the effect of the ploidy of perennial ryegrass in perennial ryegrass / white clover swards under continuous stocking by sheep (Swift *et al.*, 1990; 1993 and Vipond *et al.*, 1989). There are indications are however, of possible interactions with management systems and perennial ryegrass maturity grouping (Davies *et al.*, 1991), which need further investigation. Similarly the influence of clover leaf size on sward composition with grass / white clover swards developed under different defoliation strategies has been investigated, although further work is needed on the integration of these strategies. Some work has also been done on the influence of the imposition of a rest for a conservation cut on a continuously stocked perennial ryegrass / white clover sward and it has often been asserted that such a rest is beneficial to the white clover component of the sward (Grant and Barthram, 1990). We have still to establish, however, whether such a rest always favours the white clover component of a perennial ryegrass / white clover sward, the optimum timing of the rest and any possible interaction between the rest and with perennial ryegrass or white clover varietal characteristics.

2.1 EXPERIMENT 1 - Perennial ryegrass / white clover associations versus management.

2.1.1 Aims and objectives

Given the constraints which normally apply to grazing experiments and the criticism which can be rightly placed on the universality of the conclusions which could be drawn, the aim of this experiment was to examine the interactions between the main variants. Thus the objectives of this experiment were to examine the direct effects, combined effects, and interactions of the following variants under a continuous stocking regime with sheep:

1. perennial ryegrass maturity group;
2. perennial ryegrass ploidy;
3. white clover leaf size;
4. the imposition of a rest from continuous stocking;
5. the timing of such a rest.

The experiment was conducted using continuous stocking with sheep with swards maintained at between 35 - 55 mm sward surface height with a target height of 45 mm.

2.2 TREATMENTS

Forty associations, comprising ten varieties of perennial ryegrass (five tetraploid and five diploid) with each of four varieties of white clover (based on leaf size) were tested under four management regimes.

Table 2.1 Treatments - experiment 1

PERENNIAL RYEGRASS VARIETIES

TETRAPLOIDS			DIPLOIDS		
variety	**maturity**	**REE***	**variety**	**maturity**	**REE***
Gambit	VE	25	Frances	VE	25
Bastion	E	28	Peramo	E	28
Fantoom	I	38	Morgana	I	39
Condesa	L	53	Parcour	L	54
Belfort	VL	59	Bardetta	VL	57

* Relative Ear Emergence value

Table 2.2 Treatments - experiment 1

WHITE CLOVER VARIETIES

variety	leaf size
Aran	very large
Alice	large
Donna	medium
S184	small

Table 2.3 Treatments - experiment 1

MANAGEMENT - CONTINUOUS SHEEP GRAZING with:

CG0 no rest

CG1 six weeks rest April - late May

CG2 six weeks rest late May - early July

CG3 six weeks rest early July - mid August

2.3 EXPERIMENTAL LAYOUT and DESIGN

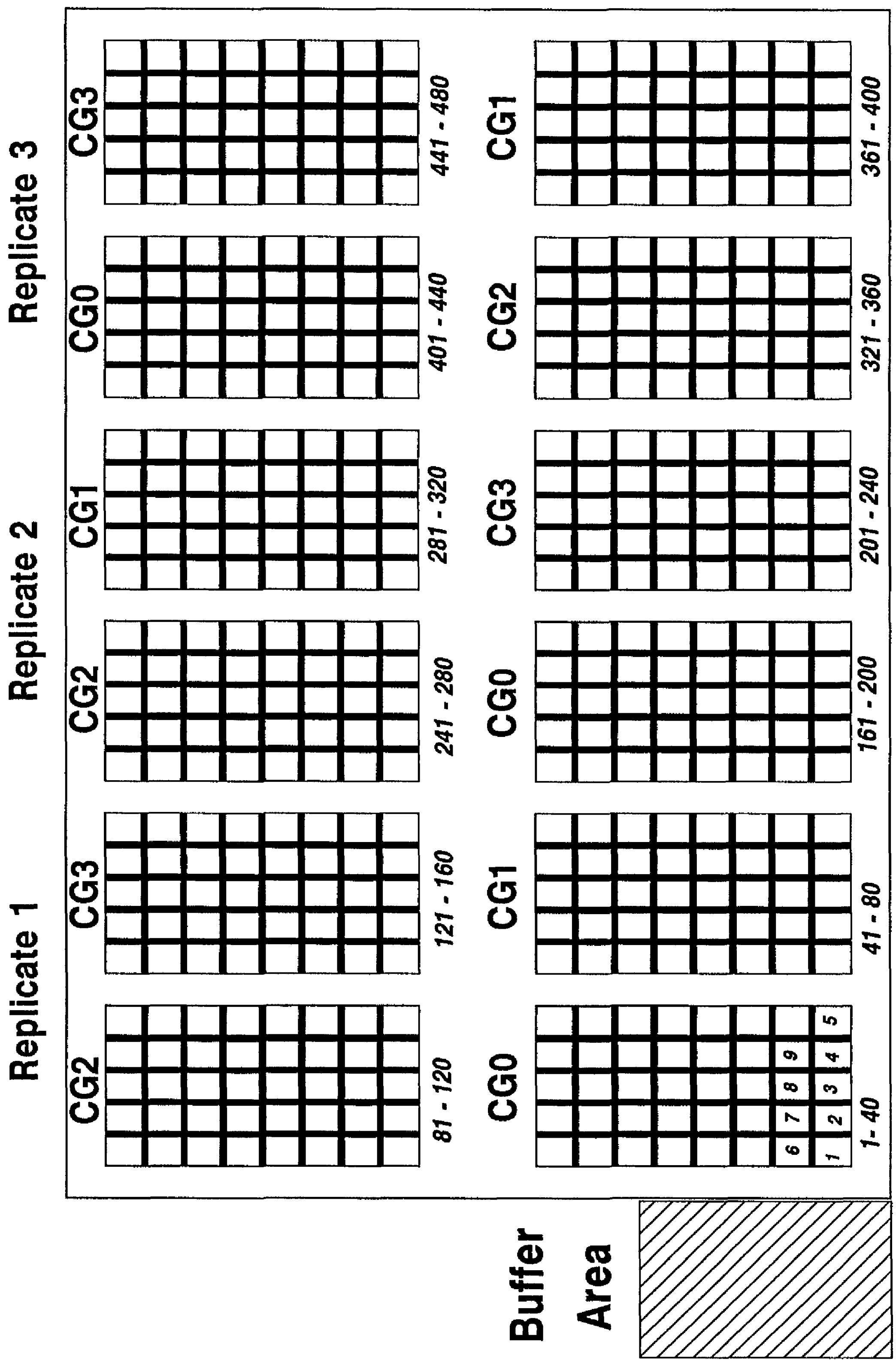
Because of the large number of combinations of variants along with the need for replication it was necessary to use mini-plots.

Table 2.4 Experimental layout and design

number of treatments	160
number of replicates	3
plot size	1m x 1m
number of plots	480

continuous stocking by sheep (target 45 mm herbage height)

Figure 2.1 Experimental Layout



2.4 SITE

Site preparation - The area used for this experiment had previously been used for crop demonstration plots. This of necessity meant that there would be small differences in the soil pH and nutrient status between the small plot areas. The initial task was to identify and minimise the impact of these differences and so the soil from each small plot area was therefore sampled (7.4.87). The whole area was then sprayed with paraquat (7.4.87) and roto-spiked to a depth of 25 cm (24.4.87). Using the soil analysis as a base-line, different rates of magnesian limestone, superphosphate and muriate of potash were applied to the plot areas to raise the pH to 6.5 and the phosphorus, potassium and magnesium status to moderate (index 2). In addition a dressing of "potassic supers" was applied to provide 70 kg P_2O_5 and 70 kg K_2O (27.4.87) for a forage rape crop. Forage rape variety Lair was broadcast over the whole area at 7 kg /ha (28.4.87). No nitrogen fertiliser was applied to this crop.

While the rape was growing the area was fenced to enable the crop to be grazed off as quickly as possible twelve weeks after sowing. It was felt that the rape crop which has a high demand for nitrogen would utilise residual nitrogen from previous crops and that the grazing sheep would spread their faeces and urine over the whole area and thereby further negate any differences in soil pH and nutrient status due to the demonstration plots. The success of these measures was confirmed by a further soil sampling and analysis the following spring just prior to commencing the management treatments. The rape was grazed down hard with sheep to minimise any rape debris.

2.5 SOWING and ESTABLISHMENT

The area was subsequently rotovated to a depth of 15 cm harrowed and a seedbed dressing equivalent to 90 kg per hectare P_2O_5 and 90 kg per hectare K_2O was broadcast over the whole area. The soil was then worked down to a very fine tilth using a hand rake and roller and marked out with string and canes (plate 2.1). The clover seed was inoculated with rhizobia and the grass and clover seeds for each plot weighed separately and put into envelopes (ie. two envelopes per plot). The seed rates used were equivalent to 30 kg per hectare and 25 kg per hectare of tetraploid perennial ryegrass and diploid

Plate 2.1 Plots marked out with canes and baler twine for sowing

perennial ryegrass respectively, both with 4 kg per hectare of white clover.

The plots were sown by hand, during the five days 7-12 August 1987, lightly raked, rolled with a hand roller and protected from birds using black thread for several weeks. Fortunately the dry spell, which had allowed uninterrupted sowing to proceed ended shortly after sowing was completed, to give way to a wetter than normal August (appendix 1), with rain encouraging rapid and even germination and emergence of grass and clover within two weeks. Establishment was good in all plots except those sown with Bardetta perennial ryegrass.

In the Bardetta plots the white clover germination was consistent with that in other associations while that of the perennial ryegrass was slow and poor. A subsequent laboratory germination test was conducted which indicated around 80% viable seeds. No seed of this variety was available from any alternative source so that resowing would involve the use of this poor seed batch. However, as some viable sown seed present in the soil might still germinate the use of an alternative variety of perennial ryegrass was out of the question. To further complicate the matter it was then too late to sow white clover effectively. It was decided therefore that complete resowing of the Bardetta associations would greatly disadvantage this treatment. The plots were therefore oversown with the original batch of Bardetta at 40 kg per hectare. The seed was dispersed in a peat / sand mixture and scattered over the appropriate plots which were then watered with a watering can. This allowed the seed to be covered with no disruption of the already established grass and clover plants. This remedial treatment produced swards of similar appearance to those of the other associations. Bardetta, like other varieties in this trial was chosen with regard to its maturity, relative ear emergence classification and ploidy in conjunction with a "1 Merit" rating for each of the three SAC areas, based on the "SAC Classified List" of grass and clover varieties for 1987. Bardetta was the only very late variety which fully met these criteria. This variety however, had its recommendation partially downgraded in 1989 and subsequently withdrawn in 1990. Throughout the experiment this variety performed poorly and sometimes gave results contrary to general trends. Where appropriate data were re-analysed with both the very late varieties omitted.

This did not give reason to change any conclusions drawn from the full data but rather increased the limits of observed trends.

The discard area round the perimeter of the trial and between blocks and the buffer area were sown on the 28th August with perennial ryegrass variety Springfield and white clover variety Donna at 25 kg and 4 kg respectively per hectare.

Twenty sheep were put into the enclosure during a dry spell at the end of October to help consolidate the seedbed, remove surplus herbage before the winter, stimulate tillering in the case of perennial ryegrass and allow light penetration to the base of the sward thereby encouraging white clover development. The sheep were removed three days later to avoid poaching, over grazing or even selective grazing of clover seedlings within the sward.

2.6 GRAZING MANAGEMENT - GENERAL

Sward surface height (SSH) has proved to be a valuable tool for use in grazing experiments and also for use in general grazing management as an indirect guide to the quantity of herbage "on offer" which can be used to help establish satisfactory grazing pressures. Initially crude visual assessments of grass height were made using a ruler (Lowman *et al.* 1984). However these took no account of sward density. The Milk Marketing Board "rising plate meter" and the Hill Farming Research Organisation "sward stick" were developed to measure sward surface height and proved effective in taking cognisance of sward density. The "rising plate meter" accounted for sward density by applying a pressure of 450 g / 900 cm^2 to the standing sward although estimates were influenced by sward variables such as its components and their growth habit and maturity. With the "sward stick", the small area of the "glass plate" (10 mm x 20 mm) meant that in an open sward, this plate penetrated deep into the canopy, even to ground level, before a strike was made. This resulted in low average readings whereas in a denser sward average readings were much higher. Both these tools therefore gave an indirect estimate of sward density and therefore of herbage "on offer".

A technique for controlling sward surface height using the sward stick, which has now been generally accepted as the most convenient, was developed by Hodgson *et al.* (1986), modified and tested by Mackie *et al.* (1987) and further refined by Hutchings *et al.* (1992). Hutchings (1992) is also currently developing a sonic sward stick which may take much of the drudgery out of such recording. The relationship between measurements from the rising plate meter and the sward stick were investigated by Davies *et al* (1986). The HFRO "sward stick" was used in both experiments 1 and 2 as an aid to maintaining prescribed sward surface heights by adjusting grazing pressures.

The large number of plots taken along with their small size meant that any attempt to graze each plot separately was impractical. The sheep were therefore given access to the whole area to be grazed. Sward surface height was measured twice a week on Tuesdays and Fridays with stocking rates adjusted accordingly. The aim was to maintain sward surface height over the two years to within the desired range of 35 mm - 55 mm with a mid range "target" height of 45 mm. This was facilitated by adjusting stock numbers as the season progressed (4 ewes with twin lambs early in the season, down to 3 ewes only at the end of the season). Fine tuning was achieved by moving the grazing barrier within the buffer area (figures 2.1, 2.2)

Blocks to be rested were enclosed by electrified sheep netting (plate 2.3). After the first and second silage cuts, the netting was removed and re-erected to allow another block to be rested and the opened buffer area was reduced. After the third silage cut, the netting was removed completely for that year, which allowed the swards from all treatments to adapt to a grazed habit, before the overall effect of the annual management regimes were assessed in late October when the sheep were removed.

During the winter months sheep were brought in as necessary for short periods of two to three days during the winter to keep the sward in good condition. At the end of the first full grazing year a creosote band 70 mm wide was applied centrally to the discard areas (200 mm wide) between plots to mark them and also prevent encroachment of white clover and to a lesser extent, perennial ryegrass, from plot to plot. This was done using a machine specially designed to mark sports field boundaries.

Plate 2.2 Cracks in the discard area between plots due to the lack of rain and soil moisture.

Figure 2.2 Grazing and cutting schedule

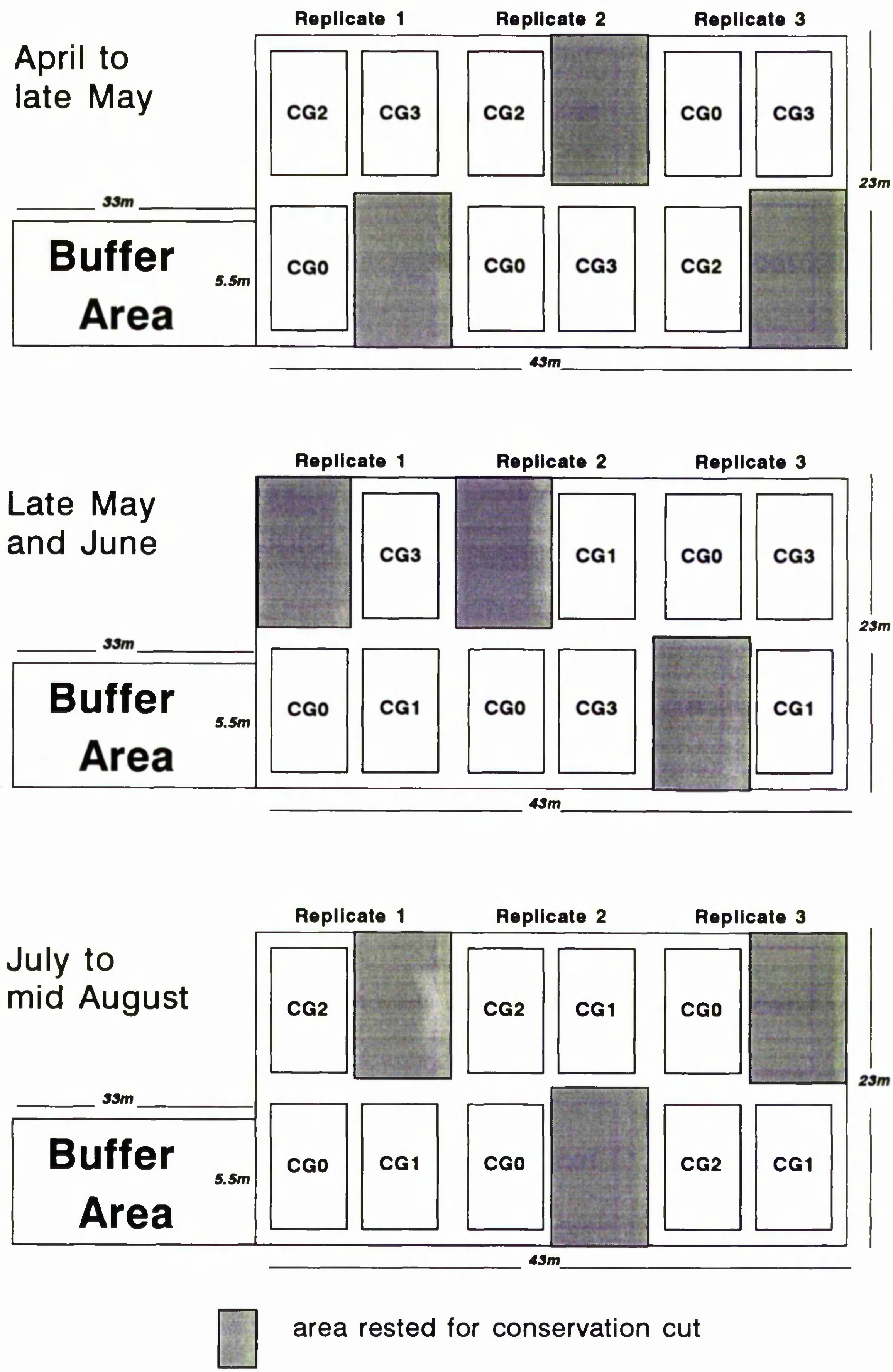


Plate 2.3 Ewes with lambs on grazed treatments were excluded from the "rested" treatments by electrified sheep netting.

Plate 2.4 Sheep graze herbage on discard areas cut herbage from a heck in the buffer area as a measure to avoid over-grazing recently rested plots.

2.7 ASSESSMENTS

Values for the percentage of white clover in swards are often used very loosely. These figures may give a useful guide to the status of the white clover component of the sward or alternatively may be quite misleading. The ambiguity with regard to such figures arises from the time of year at which the assessment was made and the grass and white clover parameters quantified. Percentage of white clover herbage in the total herbage mass at a point in time or annually is probably the most common figure quoted. Alternatively however, percentage figures could also relate to clover ground cover, clover "presence / absence" out of one hundred observations or clover plants as a components of the sward. Hodgson (1981) recognises the high degree of variability both in space and time, in most of the sward characteristics which are normally measured.

Population density in grass, is shoot ie. tiller, number per unit area (Grant, 1981). While this can be measured non destructively, it is extremely difficult, and more usually it is obtained using the core method which is described later. Tiller size and number vary considerably throughout the season, with different managements, and between grass species / varieties. Care must therefore be taken when interpreting results of individual samplings.

Population density in white clover is not so clearly defined. Possible white clover parameters which could be used are - growth points per unit area, which could give an indication of the potential for white clover growth particularly in the spring but also at any point in time; and / or, white clover stolon length or weight per unit area which gives an indication of the clover vigour at any point in time. It might be appropriate at the end of the season to give some indication of the potential of white clover to survive throughout the winter - however the amount of clover which does survive will also depend on the severity on the winter.

The main criticism of using these parameters to describe a grass / white clover sward is that they give no clear measurement of total herbage yield or of production from the white clover or grass components. They also fail to quantify changes in growth rate between the sward components throughout the season. They do however give a reliable, although tedious and time consuming, measurement of the sward state at any time along with a guide to its possible potential for growth and some indication of survival potential.

For this experiment many of parameters mentioned above could not be adopted as they involved destructive sampling procedures, such as the use of cores or turves, which were not appropriate to small $1m^2$ plots. Those used are detailed below:

Use of ten point quadrats

The use of point quadrats provides a valuable indication of the state of a grass /white clover sward. The method of using the quadrat is to set it up with the cross bar parallel to the ground. The needles are lowered into the sward, individually, either vertically or at a fixed angle and every "strike" recorded until the needle strikes the earth. In a grass / white clover sward records are kept for sown grass, white clover, weeds and bare ground (bare ground should only be recorded when it is the first strike). This gives an estimate of component species as a percentage of the sward composition. Alternatively, if only the first "strike" is recorded (or first strike records extracted from the complete data), this gives an estimate of the percentage cover of the component species (Grant, 1981).

Three Ten point quadrat assessments were made in each of the 480 plots at the end of the first full grazing system. Three parallel quadrats were set up 80 mm apart, the near the centre of each plot. The positions were approximately the same for each plot so as to avoid any bias. Once set up, using needles at both ends to level and support the cross shaft, needles were lowered until they touched the ground. Every strike was recorded under the headings - perennial ryegrass, white clover, weed and bare ground. Bare ground was only recorded when the ground was the first strike for that needle. The records of first strikes and all strikes were analysed separately.

The data from the "point quadrat" assessment made at the end of the first full year of grazing / cutting treatments were prepared, analysed and presented, to give four separate groups of data as follows:

1. "Mean number of strikes per plot" All strikes from thirty needles were recorded as they passed through the sward canopy. These were noted for each of the categories - grass, clover, weed and earth, and represent the density of the individual sward components and their relative abundances within the sward.

2. "Percentage of canopy" Strikes for each of the categories - grass, clover, weed and earth were calculated as percentages of the sum of the total number of strikes per plot. This represents the percentage of each component within the canopy.

3. "Percentage cover based on first strikes" The number of first strikes for each category - grass, clover, weed and earth was multiplied by 3.3r (ie. the first strike only for each of thirty needles). This gives an indication of the percentage sward surface cover occupied by each sward component.

4. " Canopy density based on total number of strikes per plot" The combined total number of strikes for all categories - grass, clover, weed and earth. This gives an indication of overall sward density.

These four sets of data were prepared using "Supercalc 5.1" and "Wordstar 6" and analysed separately by analysis of variance using "Genstat 5". The full "tables of results" for the point quadrat assessments are presented in appendix 2.

Use of "grid" quadrats

Grid quadrats such as a 1 m^2 quadrat "strung" with a nylon gut or wire grid to create one hundred 100 mm X 100 mm squares can be useful to monitor white clover or grass establishment, by selecting random squares and recording the number of white clover / grass seedlings per square. In an established grass white clover sward, this type of quadrat can be used to give a useful guide to clover presence and cover by counting the number of squares in which white clover occurs. This technique is a modification of that used by Grime and Lloyd (1973) and Gooding (1975).

Grid quadrats ($0.64m^2$ quadrats - subdivided into 100 80 mm x 80 mm squares) were used to assess clover abundance at the end of both first and second full grazing seasons. The grid quadrat was located in the centre of a $1m^2$ wooden frame which fitted exactly over the $1m^2$ plot. A ten centimetre discard area was thereby established to eliminate any possible plot edge effect. The number of squares in which any part of a white clover plant was observed was recorded.

Data from the "grid quadrat" assessments made at the end of the first full grazing / cutting year, after overwintering between years and after the second full grazing / cutting year were likewise processed and using "Supercalc 5.1", "Wordstar 6" and analysed by analysis of variance using "Genstat 5". The tables of results from the grid quadrat assessments give an indication of white clover presence and abundance and are presented as:

$0.64m^2$ Quadrats: Number of 80 mm x 80 mm squares in which white clover was present - out of 100.

Tables for single treatment effects and for significant interaction effects are included in chapter two. Tables for non significant interactions are in appendix 3.

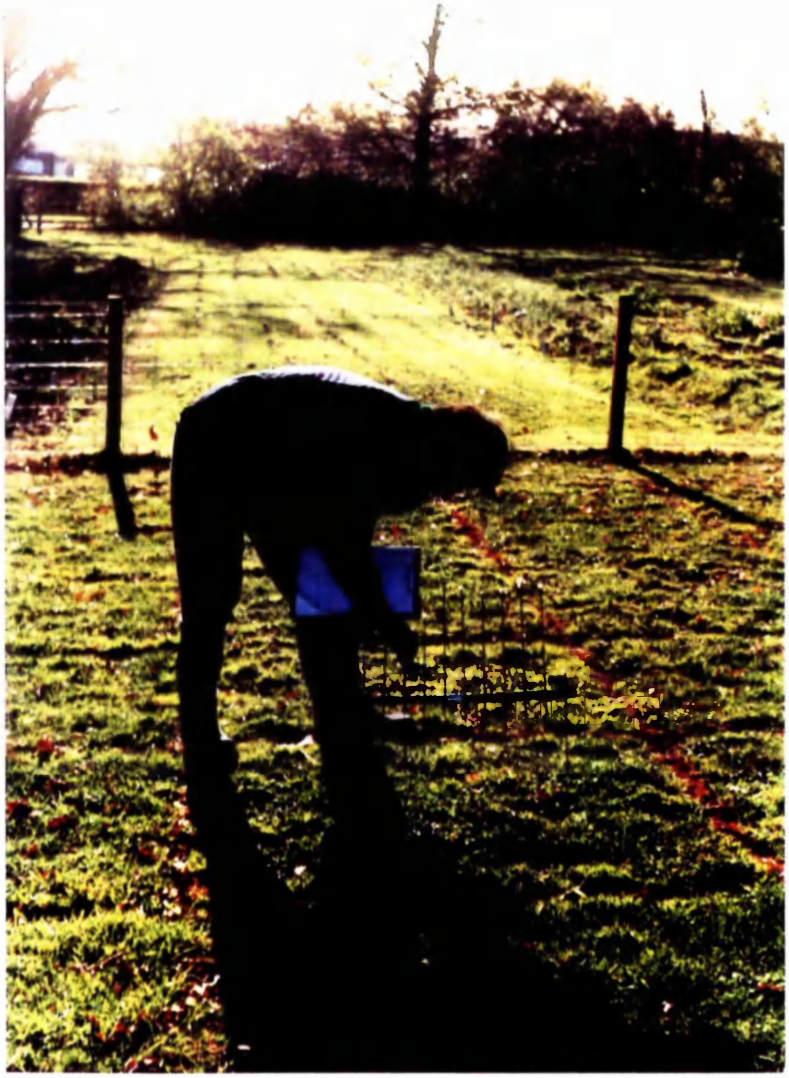


Plate 2.5 Use of "Ten point quadrat"

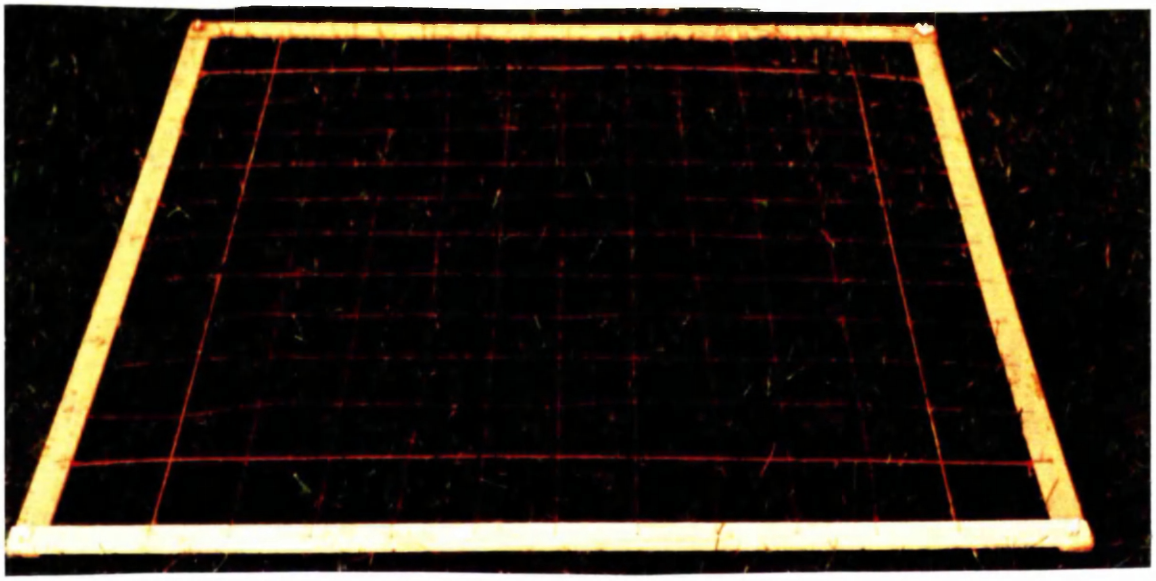


Plate 2.6 "Grid quadrat" (0.64 m^2 quadrat - within orange strings - subdivided into 100 8 cm x 8 cm squares). The 1 m^2 square wooden surround fitted exactly over each plot.

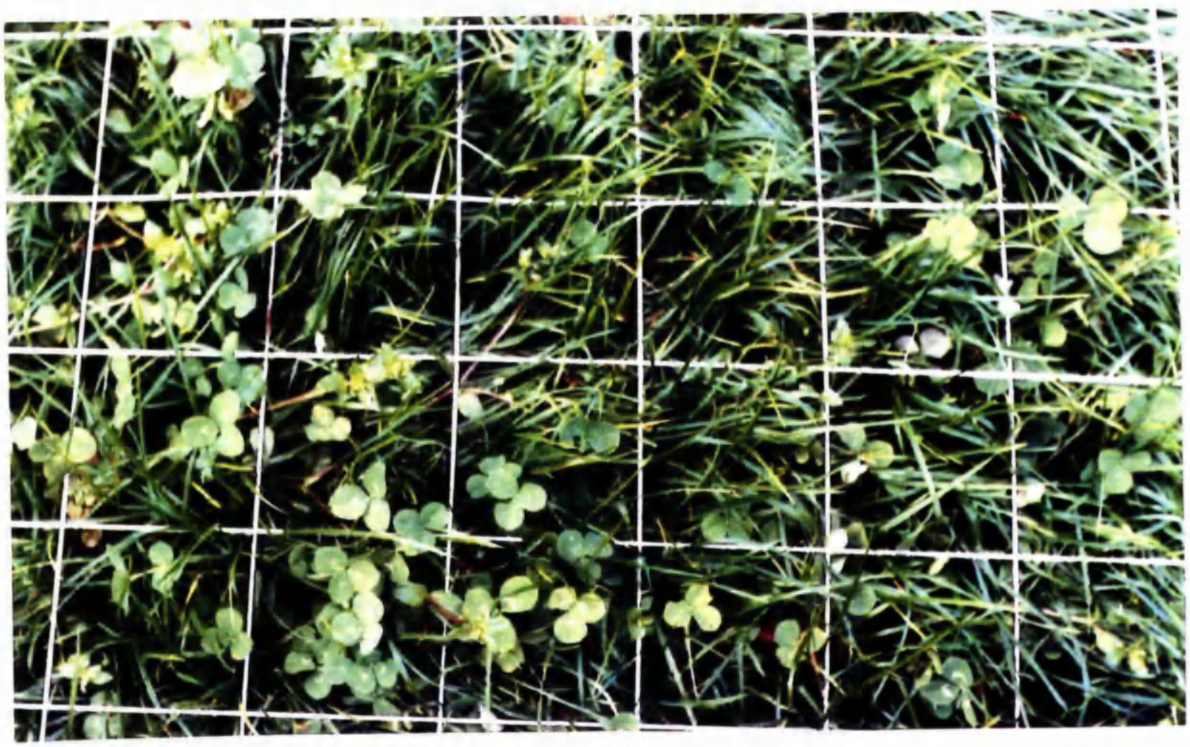


Plate 2.7 Close up of "Grid quadrat". The number of squares in which white clover was present out of 100 was recorded

Plate 2.8 Plots marked with creosote to prevent spread of clover from plot to plot.

2.7.1 The timing of "ten point" and "grid" quadrat assessments

The varietal characteristics of growth habit, leaf and petiole size and partitioning of nutrients within white clover are influenced and modified by time of year and grazing / conservation management. It would therefore have been very informative to have been able to monitor these changes throughout the season. To assess the 480 plots, however, using the "ten point quadrat" took about twelve full days while with the grid quadrat the assessment took about five days. To monitor the changes would not have allowed time for grazing management, conservation cuts with associated botanical analysis. It was also considered that, while such seasonal information would have been of value the period of time which would have elapsed during any mid season assessment would have allowed changes in sward characteristics to occur during the period of assessment especially in plots in transition between rested and continuous stocking managements. It was decided therefore to withhold assessments until the end of October, immediately after the sheep were removed. It was considered that by delaying until this time, rapid changes in sward state were unlikely and both the white clover and the perennial ryegrass in all treatments would have adapted to a sheep grazing habit and that the overall, long term effect of the grazing / rest management treatments would be best assessed. This was in keeping with the findings of Collins *et al.* (1991) where the reserve of white clover stolon in late autumn and early winter proved to be a major factor influencing the yield of white clover the following year.

A post-winter establishment "grid assessment" was made at the beginning of April of the first full grazing year. This showed white clover presence of over 97 out 100 squares in all perennial ryegrass / white clover associations which demonstrated uniformity of swards before the application of management treatments. The combined effect of experimental treatments, winter conditions and winter management was assessed using a "grid" assessment in early April of the second full grazing year.

Table 2.5 - The effect of the imposition and timing of a rest, for a conservation cut, on the presence of white clover in perennial ryegrass / white clover swards, continuously stocked with sheep.

$0.64m^2$ quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Timing of assessment		Rest period				SED	F pr.
Grazing Year (after establishment year)	Month	None	April-late May	late May & June	July-mid August		
1 (post grazing)	Oct / Nov	73.65 (73.4)	72.66 (71.5)	69.61 (70.2)	73.80 (74.4)	11.53 (11.47)	0.980 (0.982)
2 (pre-grazing)	Mar / Apr	54.6 (55.1)	46.6 (45.3)	47.8 (49.2)	48.5 (49.3)	5.51 (6.02)	0.525 (0.492)
2 (post grazing)	Oct / Nov	48.1 (48.0)	32.7 (32.8)	48.2 (49.7)	67.3 (68.4)	7.59 (7.87)	0.022 (0.023)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

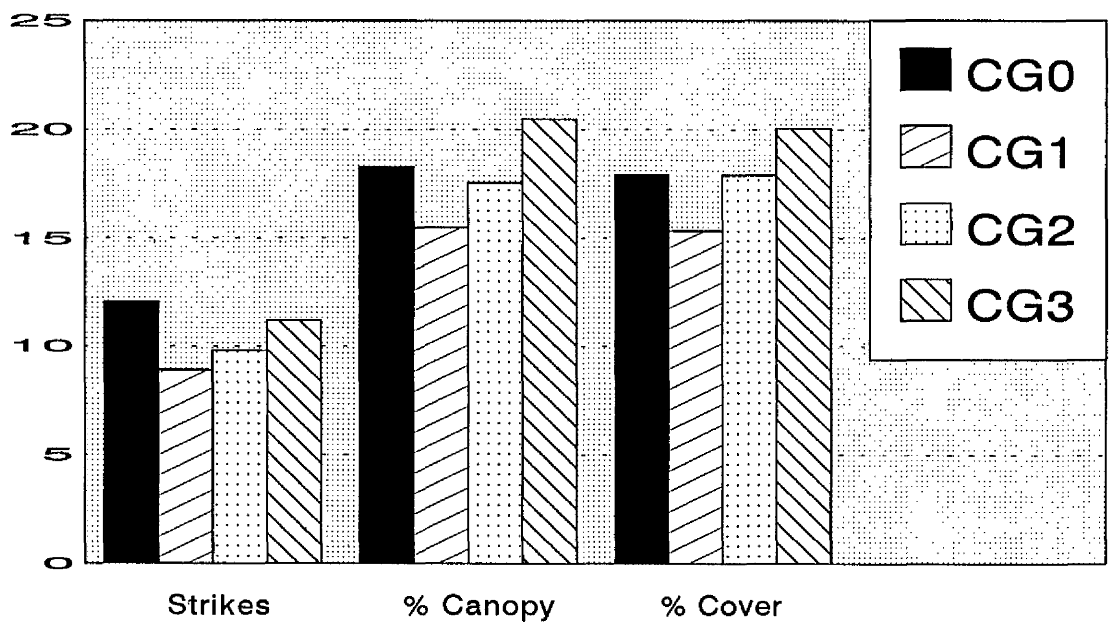
2.8 RESULTS

2.8.1 Single treatment effects

2.8.1.1 The value and timing of a rest from continuous stocking by sheep for a silage cut.

When no cognisance is given to white clover leaf size or perennial ryegrass varietal characteristics, point quadrat and grid quadrat assessments taken at the end of the first treatment year, indicated that the imposition of a rest treatment of about six weeks from

Figure 2.3 Sward white clover contents - Rest treatments
Point quadrat data (extracted from tables 11.1. 11.2 & 11.3)



continuous sheep stocking, to allow a conservation cut, had no significant effects on sward white clover contents as demonstrated in figure 2.3 and table 2.5. However, it was noted from both point and grid quadrat assessments, that blocks which had been rested during April to late May contained less white clover than those which were continuously stocked, while those which were rested during July to mid August contained a greater proportion of white clover than the continuously stocked blocks.

By the end of the second year, during which the treatments were applied, these small differences in sward white clover contents, established during the first treatment year, had developed further to show significant differences between management treatments as shown in table 2.5. The rest during July to mid August gave a clear and significant increase in sward white clover content, whereas, a rest during the traditional "first cut" period April to

Table 2.6 - The effect of ploidy of perennial ryegrass on the presence of white clover in perennial ryegrass / white clover associations under continuous stocking by sheep.

0.64m² quadrats: Number of 8cm x 8cm squares in which white clover was present (out of 100)

Timing of assessment		Perennial ryegrass ploidy		SED	F pr.
Grazing Year (after establishment year)	Month	Tetraploid	Diploid		
1 (post grazing)	Oct / Nov	74.15 (74.8)	70.71 (70.0)	1.493 (1.662)	0.022 (0.004)
2 (pre-grazing)	Mar / Apr	52.3 (53.2)	46.4 (46.3)	2.33 (2.62)	0.011 (0.009)
2 (post grazing)	Oct / Nov	53.4 (53.5)	44.8 (45.9)	2.12 (2.38)	<0.001 (0.002)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

late May, greatly reduced the sward white clover content. A rest during late May and June was found to have no significant effect on the white clover status of the sward.

2.8.1.2 The importance of perennial ryegrass ploidy as a factor in the determination of the proportion and persistence of white clover in perennial ryegrass / white clover associations.

Perennial ryegrass ploidy proved to be an important factor in determining sward white clover contents by the end of the first treatment year, as shown in figure 2.4 and table 2.6. Point quadrat records of white clover strikes analysed as mean number of strikes per plot, percentage of canopy and percentage cover all showed higher white clover contents in tetraploid perennial ryegrass / white clover associations than in diploid perennial ryegrass / white clover associations. This trend was confirmed by all "grid quadrat" assessments (table 2.6). A highly significant pattern was established by the final white clover presence assessment at the end of the second treatment year showed clover presence percentages of 53.4 in the tetraploid perennial ryegrass / white clover associations compared with 44.8 in the diploid perennial ryegrass / white clover associations (table 2.6).

Figure 2.4 Sward white clover contents - PRG Ploidy
Point quadrat data (extracted from tables 11.5. 11.6 & 11.7)

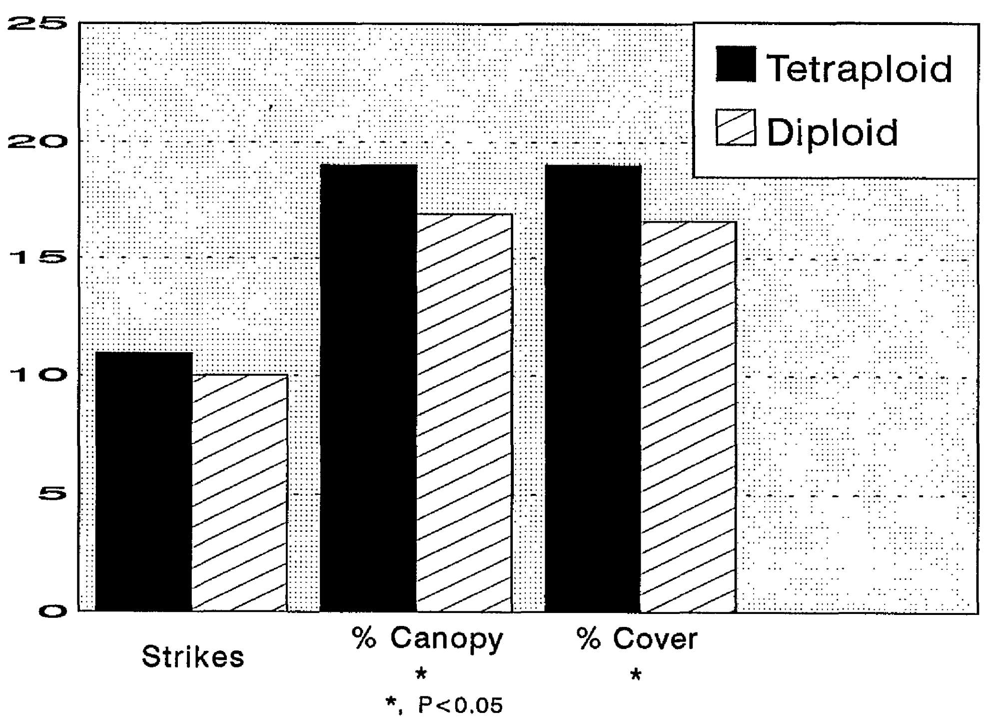


Table 2.7 - The effect of perennial ryegrass maturity group on the presence of clover in perennial ryegrass / white clover associations under continuous stocking by sheep.

0.64m^2 quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Timing of assessment		Perennial ryegrass maturity group					SED	F pr.
Grazing Year (after establishment year)	Month	VE	E	I	L	VL		
1 (post grazing)	Oct / Nov	74.66	71.67	72.49	70.74	72.59	2.361	0.555
2 (pre-grazing)	Mar / Apr	57.8	50.1	49.5	41.5	47.9	3.68	<0.001
2 (post grazing)	Oct / Nov	54.1	50.9	48.6	45.3	46.6	3.36	0.070

Consistently higher numbers of grass strikes in the diploid perennial ryegrass / white clover associations and correspondingly high earth and weed strikes in the tetraploid perennial ryegrass / white clover associations suggest that the more open tetraploid sward (appendix 2 - table 11.8) encourages sward white clover contents.

2.8.1.3 The influence of perennial ryegrass maturity group on the presence and persistence of white clover within perennial ryegrass / white clover associations.

The effects of perennial ryegrass maturity were less clear than for other treatments and took longer to be evident. By the end of the first treatment year no significant differences in sward white clover contents due to perennial ryegrass maturity group were observed at the 95% confidence level or above.

Differences became apparent after the winter between treatment years and these persisted during the second treatment year. These are demonstrated in the "grid quadrat" assessments (table 2.7) and showed a clear and consistent trend of decreasing white clover contents from very early perennial ryegrass / white clover associations, through early and intermediate to late perennial ryegrass / white clover associations. This trend did not extend to very late perennial ryegrass / white clover associations. Point quadrat data (appendix 2 - tables 11.9, 11.10, 11.11, 11.12) showed late perennial ryegrass values for percentage of canopy and for percentage cover were significantly higher than for other maturity groups.

Table 2.8 - The effect of clover leaf size on the presence of clover in perennial ryegrass / white clover associations under continuous stocking by sheep.

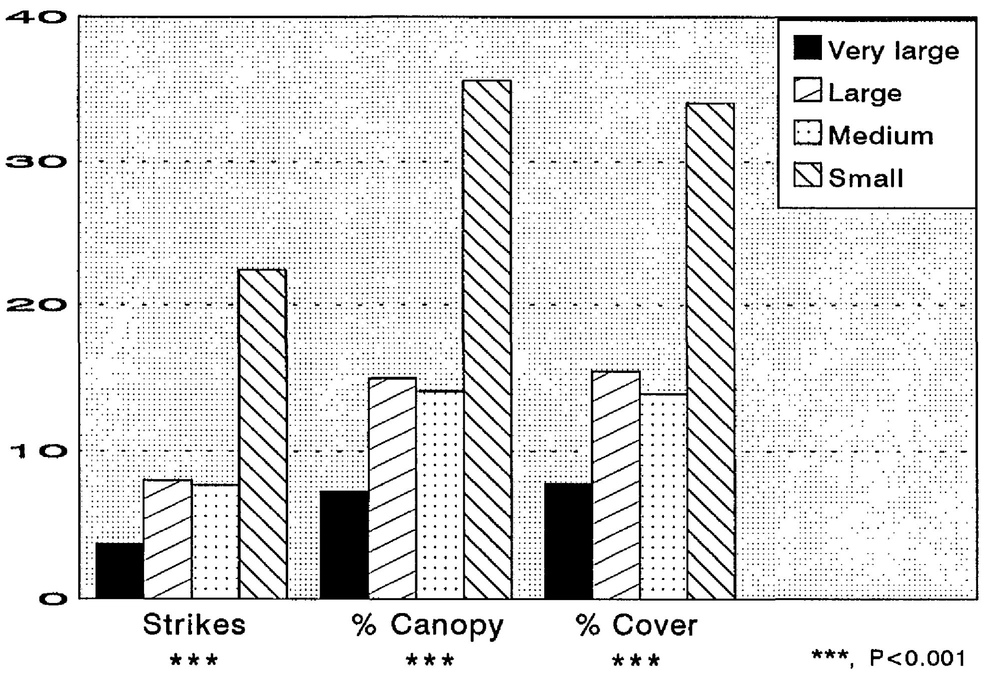
$0.64m^2$ quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Timing of assessment		Clover leaf size				SED	F pr.
Grazing Year (after establishment year)	Month	VL	L	M	S		
1 (post grazing)	Oct / Nov	45.81 (45.5)	70.70 (69.8)	77.81 (78.7)	95.40 (95.6)	2.111 (2.35)	<0.001 (<0.001)
2 (pre-grazing)	Mar / Apr	15.0 (15.1)	46.4 (46.6)	40.6 (41.9)	95.5 (95.3)	3.29 (3.70)	<0.001 (<0.001)
2 (post grazing)	Oct / Nov	20.9 (21.3)	44.3 (44.6)	36.7 (38.1)	94.5 (94.9)	3.00 (3.37)	<0.001 (<0.001)

2.8.1.4 The influence of white clover leaf / petiole size on the presence and survival of white clover within perennial ryegrass / white clover associations.

The importance of white clover leaf / petiole size to the presence and persistence of white clover in perennial ryegrass white clover associations was shown to be highly significant in both "point quadrat" and "grid quadrat" assessments (figure 2.5; table 2.8).

Figure 2.5 Sward white clover contents / White clover leaf size
Point quadrat data (extracted from tables 11.13. 11.14 & 11.15)



No significant difference was observed in this regard between medium and large leaved white clover with percentage canopy levels and percentage cover levels. Small leaved white clovers maintained mean clover presence levels at between 94.5% and 95.5% over both years (table 2.8), whereas the white clover presence levels in the very large, large and medium leaved white clover associations were observed to drop from 45.8% to 20.9%, 70.7% to 44.3% and 77.8% to 36.7% respectively.

Table 2.9 - The interaction of clover leaf size and the imposition and timing of a rest for a conservation cut, on the presence of clover in perennial ryegrass / white clover swards,continuously stocked with sheep.

0.64m² quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Rest period	Clover leaf size				SED	F pr.
	VL	L	M	S		
October / November Post grazing assessment after first full grazing year after establishment year.						
No rest	41.63	74.00	81.03	97.93	12.10	<0.001
April-late May	49.33	64.13	79.23	97.93		
late May & June	37.20	67.50	76.03	97.70		
July-mid August	55.07	77.17	74.95	88.03		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.						
No rest	19.9	47.6	55.8	95.0	7.93	0.057
April-late May	14.2	38.0	39.2	95.0		
late May & June	10.8	46.6	35.2	98.6		
July-mid August	15.0	53.5	32.0	93.3		
October / November Post grazing assessment after the second grazing year after the establishment year.						
No rest	20.6 (20.2)	41.1 (40.0)	34.5 (36.2)	96.3 (95.7)	9.20 (9.80)	<0.001 (<0.001)
April-late May	8.3 (8.1)	19.3 (18.9)	18.6 (18.2)	84.8 (86.0)		
late May & June	13.7 (15.0)	45.4 (46.7)	34.0 (37.3)	98.9 (99.8)		
July-mid August	41.1 (42.0)	71.4 (72.7)	59.6 (60.8)	97.0 (98.0)		

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

2.8.2.1 Two treatment interaction effects between "rest" treatments and sward components on white clover presence and cover.

White clover leaf size

Much more striking results were obtained when the value and timing of a rest was examined with regard to white clovers of different leaf / petiole size (table 2.9). With small leaved white clover varieties, a rest during April to late May caused only a slight and barely significant reduction in sward white clover content with no significant differences between no rest and other rest timing treatments. With the larger leaved white clovers, the indications were that the larger the leaves / petioles, the greater the harmful effect of a rest April to late May and the greater the benefit of a rest for a conservation cut during July to mid August.

Perennial ryegrass maturity group

On examining the combined effects of perennial ryegrass maturity group and the imposition and timing of a rest from continuous stocking (appendix 3 - table 12.1) no overall significant interaction was observed.

Perennial ryegrass ploidy

Similarly, no overall significant interaction was observed between the effect of perennial ryegrass ploidy and those of the imposition and timing of a rest for a conservation cut on clover presence (appendix 3 - table 12.2). Tetraploid perennial ryegrass / white clover associations consistently contained more white clover than diploid perennial ryegrass / white clover associations. However the adverse influence of an early rest and the favourable influence of a later rest were more pronounced in the case of diploid varieties.

2.8.2.2 Interaction effects between perennial ryegrass ploidy and other sward component characteristics.

White clover leaf size

With regard to the combined effects of clover leaf size and perennial ryegrass ploidy (appendix 3 - table 12.3) no clear interaction was observed. The individual treatment effects were clearly visible. Tetraploid perennial ryegrass associations had consistently more white clover than diploid perennial ryegrass associations and persistence of white clover was greatest with small leaved and least with very large leaved white clover varieties. However the fact that the large leaved white clover association contained more white clover than the medium leaved white clover associations at the end of the second year was difficult to explain.

Perennial ryegrass maturity group

Analysis to investigate any interaction effects between perennial ryegrass ploidy and perennial ryegrass maturity on sward white clover contents (appendix 2 - tables 11.17, 11.18, 11.19, 11.20; appendix 3 - table 12.4) failed to show any clear pattern. White clover contents in tetraploid perennial ryegrass / white clover associations were consistently higher in tetraploid than in diploid perennial ryegrass / white clover associations with the exception of the very late diploid perennial ryegrass (Bardetta) / white clover association, which had more white clover than its tetraploid counterpart at the end of the first year. This could be attributed to the lack of vigour associated with the poor quality Bardetta seed used. "Point quadrat" records of grass strikes (appendix 2 - table 11.17) confirm the poor stand of perennial ryegrass in this treatment. The white clover content in this association fell to the lowest overall at the end of the second year. This was probably as a result of the establishment of annual meadow grass facilitated by the lack of perennial ryegrass competition. Once again white clover contents were higher in associations of earlier rather than later associations.

2.8.2.3 The effect of the remaining two treatment interaction between white clover leaf size and perennial ryegrass maturity group.

No significant interaction was observed (appendix 3 - table 12.5) although the individual treatment effects of these variants were clearly demonstrated.

2.8.3 Three treatment interaction effects.

No statistically significant interactions were observed at this level (appendix 3 - tables 12.6, 12.7, 12.8, 12.9). Individual treatment and some two treatment interactions were clearly visible making the tables useful for highlighting the most appropriate sward components and cutting / grazing managements for the maintenance of white clover proportions in the sward. These tables clearly show that very large leaved white clover / perennial ryegrass swards are inappropriate to management systems involving continuous stocking with sheep. They also show that taking a conservation cut from these swards at normal first cut silage time (during April to late May) severely reduced the white clover content whereas a rest during July to mid August encouraged white clover. Small leaved white clover / perennial ryegrass swards, on the other hand, were ideally suited to management systems involving continuous stocking with sheep. Rest treatments were not required to maintain white clover levels in these swards, but when they were applied the timing of the conservation rest was not critical to the survival and maintenance of adequate white clover levels. The, albeit small, reduction in white clover presence due to the earlier cut was greatest in the later maturing diploid swards.

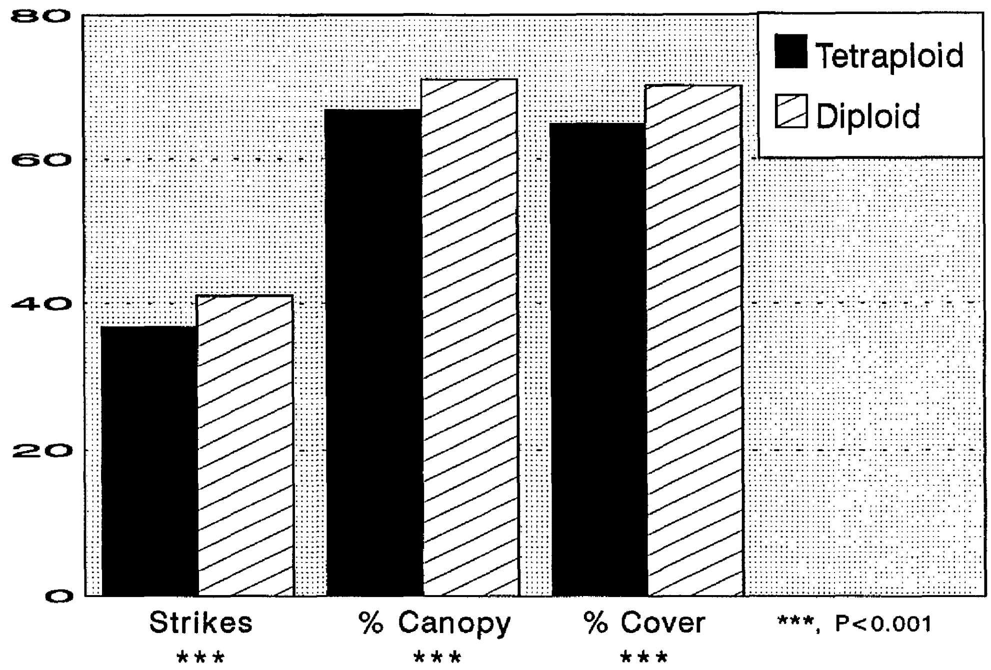
Diploid perennial ryegrass / white clover swards consistently contained slightly less white clover than the tetraploid perennial ryegrass / white clover swards. The adverse competition from the more densely tillered diploid perennial ryegrass was most severe with the intermediate and to a lesser extent with the late and very late diploid perennial ryegrasses and this harmful effect increased with increasing white clover leaf size. These vulnerable diploid perennial ryegrass / white clover swards had their white clover proportions greatly enhanced by a conservation rest during July and early August and conversely depressed by an early (April to late May) rest.

2.8.4 Treatment effects on the perennial ryegrass sward component

Highly significant grass strike values from each of the three sets of "point quadrat" data, (summarised in figure 2.6) in which grass values showed diploid perennial ryegrass white clover associations to have:

1. denser grass stands than tetraploid perennial ryegrass associations;
2. higher grass percentages than tetraploid perennial ryegrass associations;
3. higher grass cover percentages than tetraploid perennial ryegrass associations.

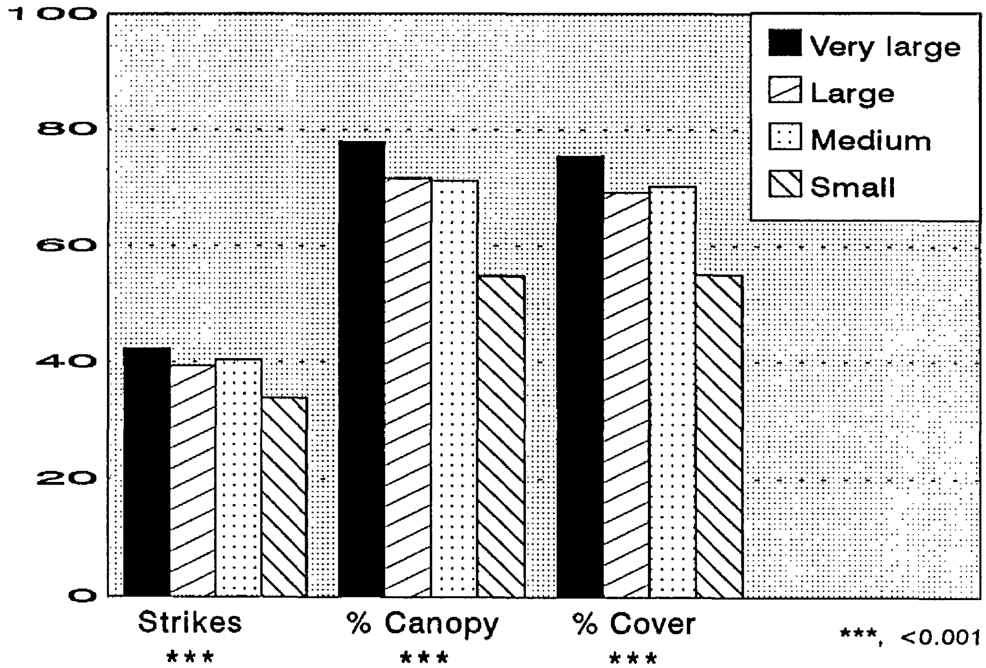
Figure 2.6 Sward PRG contents / PRG ploidy
Point quadrat data (extracted from tables 11.5, 11.6 & 11.7)



The "point quadrat" data in appendix 2 - tables 11.5, 11.6 and 11.7 also shows the weed and earth components to be greater in the tetraploid than in the diploid perennial ryegrass / white clover associations. The overall density of the swards was greatest in the diploid perennial ryegrass / white clover associations (appendix 2 - table 11.8).

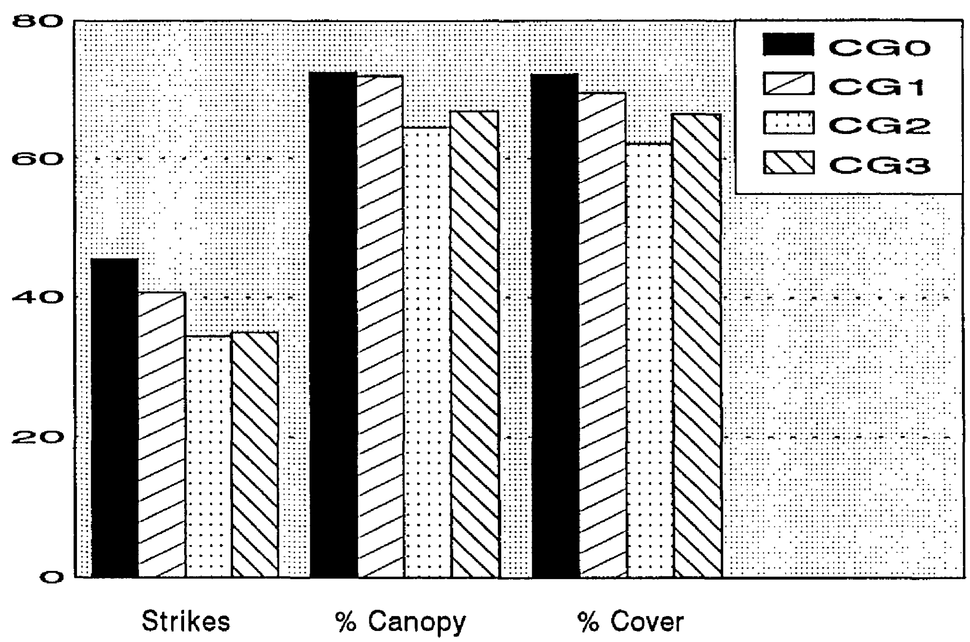
With regard to the effect of white clover leaf size on the grass component of the swards the "point quadrat" data show highly significant trends. As one might expect (figure 2.7), where white clover percentage values were high, then the other sward components including grass were lower. This does mean that grass quantities were necessarily reduced. However, in this case, results of mean number of strikes per plot and percentage cover showed clearly that where white clover density and cover are high, grass density and cover were reduced. Highly significant canopy density values (appendix 2 - table 11.16) showed sward density to increase as white clover leaf size decreased.

Figure 2.7 Sward PRG contents / White clover leaf size
Point quadrat data (extracted from tables 11.13, 11.14 & 11.15)



With regard to the effect on the perennial ryegrass component of perennial ryegrass / white clover associations, of the imposition and timing of a rest for a conservation cut, from continuous stocking by sheep, several highly significant and interesting trends were observed.

Figure 2.8 Sward PRG contents / Rest Management
Point quadrat data (extracted from tables 11.1, 11.2 & 11.3)



Mean number of strikes per plot demonstrated that the grass in unrested swards was the most dense, next swards rested April to late May while little difference between swards rested late May and June and July to mid August. The lower number of grass strikes in swards rested in late May and July compared with July to mid August as seen in the percentage of canopy and percentage cover assessments was probably due to the increased broad leaved weed competition due to the rest during the period of peak weed growth in late May and June. Values for canopy density (appendix 2 - table 11.4) showed the thickest sward where no rest was given, and where rested, progressively later rests resulted in progressively thinner swards.

2.9 DISCUSSION

The main strength of this experiment must be that a wide range of variables, in terms of sward components and cutting / grazing managements were tested in one experiment under actual continuous stocking with sheep, under uniform conditions. It was not possible unfortunately to include the effects of different sward surface heights, rotational grazing or cattle grazing. Care should therefore be taken if attempting to extrapolate the conclusions from this work to cover situations not directly tested.

As outlined earlier, the large number of treatments necessitated the use of small plots ($1m^2$) ruling out any attempt to graze plots individually. Sheep were therefore free to graze all plots other than those being rested. The fact that sheep were given access to the whole area with plots not individually fenced, could give rise to the criticism that the sheep would selectively graze some plots while rejecting others. There was however no evidence of this. As with all grazing, although average sward surface height over the grazed area may be relatively uniform the actual herbage height varies greatly especially at higher herbage heights. This is because the grazing animal endeavours to take a full bite, with a minimum of walking between bites. Thus herbage height will vary and can often be observed to change in bands or waves across the grazed area. This was the case with this trial with changes in average herbage height associated with the progress of sheep across the area with no indication of selection between plots. It was felt however, that while sheep did not appear to be discriminating between plots this should be tested objectively. Measurements of sward surface heights for individual plots were therefore made in May and again in June of the first treatment year. The method and outcome of one of these assessments made in late May of the first harvest year, are as follows.

Five random sward surface height readings were taken, using the HFRO sward stick within each of the 360 square meter plots being grazed at that time. These were then analysed using "Genstat 5". Significant differences were found between the sward surface height on plots of maturity group and ploidy (table 2.10).

Table 2.10 The effects of perennial ryegrass ploidy and maturity group on the sward surface height SSH (mm) of individual plots under an overall SSH of 45 mm.

PRG ploidy	Perennial ryegrass maturity group					SED	F pr.
	very early	early	intermediate	late	very late		
tetraploid	45	42	46	36	40	2.27	<0.001
diploid	52	48	54	45	34		

Perennial ryegrass maturity group					SED	F pr.
very early	early	intermediate	late	very late		
48	45	50	40	37	1.61	<0.001

Perennial ryegrass ploidy			
tetraploid	diploid	SED	F pr.
42	47	1.02	<0.001

While it could be argued that the lower heights in the tetraploid and later maturing perennial ryegrass plots resulted from selective grazing of the more palatable tetraploid or "younger" later varieties, it was considered that the differences were in line with what it was reasonable to expect as the result of the more open tetraploid sward and less vigourous regrowth after grazing of later varieties (especially in the case of Bardetta), early in the season. Under the harder grazing regime that operated during the summer of 1988 stock did not have the luxury of choice and therefore the opportunity to graze selectively was small.

During the first experimental year, however, sward height was maintained at around the 45 mm target until after the first cut at the end of May. The exceptionally low rainfall during the early summer of 1988 (appendix 1) meant that during the months of June and July, herbage growth was very slow and for a time practically stopped. In theory it should be possible to maintain sward surface height by increasing the grazing area using "grass buffers", perhaps together with reducing stock numbers. If herbage growth stops, under continuous stocking sward surface height must fall. During the summer of 1988 therefore, sheep numbers were cut to a minimum, the buffer area was fully opened and surplus herbage from the conservation cuts was fed within the buffer area. The lowering of sward surface height during this period could not be avoided and for most of the critical summer months it remained about 35 mm. This meant that the perennial ryegrass / white clover associations were subjected to particularly hard grazing. During the second grazing year (1989), sward surface heights were maintained at 45 mm up to first cut and allowed to rise towards 55 mm during July and August and then lowered to 35 mm by late October. 1989 produced an even drier summer, especially during May, June and July (appendix 1). During this period, sward surface heights were maintained by extending the buffer area to a non fertilised grass area out with, but adjacent to, the trial area for a few days.

During the period immediately after the rested / cut plots were opened up for grazing, particular attention was given to grazing behaviour. It had been suggested that with the introduction of fresh grazing, the sheep would move from grazed pasture to fresh pasture before the white clover had had enough time to change from a rested habit (stolons with longer internodes / not clinging to the ground surface) to a grazed growth habit. It followed therefore that the fresh area would suffer from over grazing during a vulnerable period. It was considered once again however, that during 1988 the hard grazing regime did not allow stock the luxury of choice and therefore the opportunity to select was small. To further ensure that this problem did not occur the discard area around the rested blocks was not cut, some of the herbage from the conservation cut was left on the discard areas and also some was made available from a feeder near the buffer area (plate 2.4). The sheep ate this for a few days whilst also grazing the plots. The strategy seemed to work as there was no evidence to indicate that the "fresh" plots were being over - grazed. The indication from this experiment (also from experiment 2) was that rather than move immediately to a previously rested area, there was a reluctance to move to "pastures new" and that sheep preferred to graze a currently grazed sward.

With regard to the sward assessments, the point quadrats, although time consuming, were useful in describing sward density, sward components and species cover. The grid method, however, was found to be the most useful both in terms of speed and sensitivity to differences in white clover abundance.

As the experiment was investigating, among other things, the effects of white clovers of different leaf size and associated petiole length it might be argued that the grid method introduced a bias in favour of large petioled / leaved white clover varieties. The argument being that a single plant of a large leaved type may be recorded in several squares whereas a single plant of a small petioled / leaved white clover may only occur in one. It was observed however, that at a sward surface height of 35 mm - 55 mm large petioled varieties did not have long petioles and leaf size was modified in response to close grazing (details and discussion of leaf size and petiole lengths are presented in chapter 3 and figure 3.5). These measurements however show that this criticism was not valid in practice.

Let us now consider the results and deal firstly with the sward components. The comparison between diploid and tetraploid varieties of perennial ryegrass consistently and highly significantly showed that tetraploid perennial ryegrass / white clover associations contained more white clover than diploid swards of equivalent perennial ryegrass maturity group and white clover leaf size (Collins, 1985, Frame, 1985a, Davies, 1985, and Swift *et al.*, 1990, 1992a, b & c and 1993). This advantage of tetraploid over diploid perennial ryegrass was, nevertheless small, which agrees with Frame (1985a) and Lex and Simon (1991). Within a continuously sheep grazed situation, the greater amount of white clover in association with tetraploid perennial ryegrass can be attributed to the more open, less densely tillered tetraploid associations allowing more physical space and better light penetration to foster white clover development.

In keeping with the observations of Frame (1985a), the impact of perennial ryegrass maturity group, in terms of white clover presence was less clear and statistically not significant. However, a consistent trend of decreasing white clover contents from very early perennial ryegrass / white clover associations, through early and intermediate to late perennial ryegrass / white clover associations was observed. The existence of this trend is supported by the findings of Lex and Simon (1991), who found falling levels of white clover in association with late perennial ryegrass in the second year of their experiment, and by the work of Davies *et al.* (1991) who found progressively lower white clover percentages in perennial ryegrass / white clover associations containing progressively later perennial ryegrass varieties. This could well be attributed to the increased tillering capacity associated with progressively later maturing perennial ryegrasses. This trend may not extend to very late perennial ryegrass / white clover associations which may be less aggressive than late varieties. This is supported by the high values for late perennial ryegrass as a percentage of canopy and for percentage cover which were significantly higher than for other maturity groups. However the failure of this trend to extend to the very late perennial ryegrass associations in this investigation may be due to the poor Bardetta establishment.

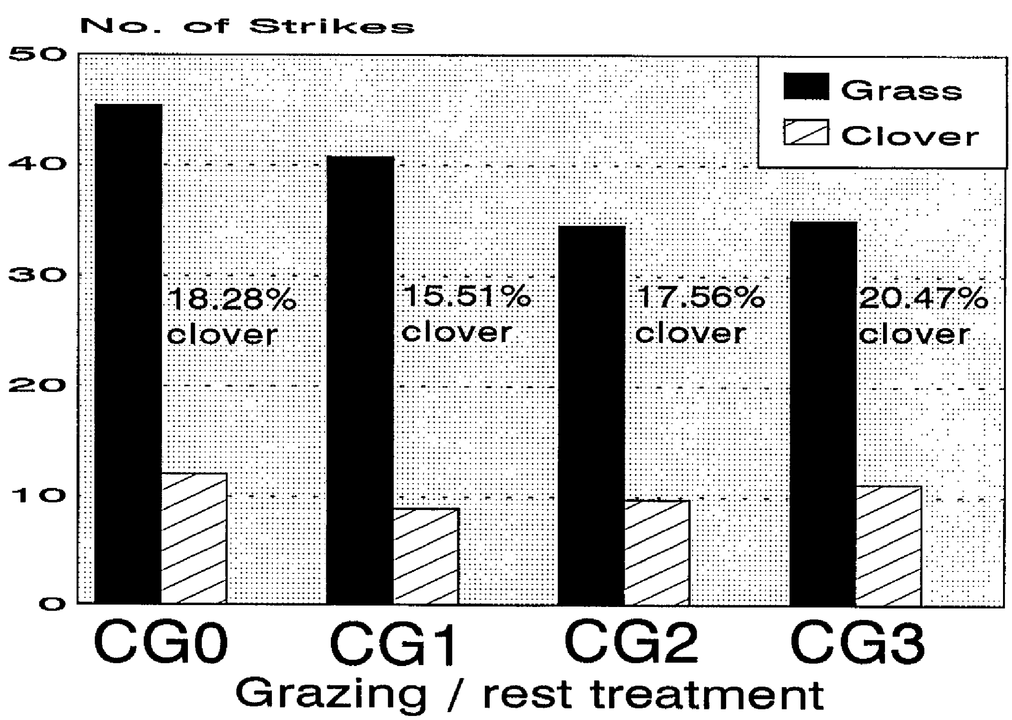
No significant interaction was observed between perennial ryegrass ploidy and perennial ryegrass maturity group in terms of sward white clover contents. Nevertheless, the combined effects of the individual treatments noted above meant that a combination of earliness and tetraploidy of perennial ryegrass variety offered the best opportunity for white clover development. Thus at the end of the second treatment year, the very early tetraploid perennial ryegrass / white clover associations had the highest overall white clover contents, while the very late diploid perennial ryegrass / white clover associations had the overall lowest white clover contents. However, the very early and early diploid perennial ryegrass / white clover associations had greater white clover contents than the late tetraploid perennial ryegrass / white clover associations. This supports the findings of Davies *et al.* (1991) who recorded white clover contents of 15% in a very early diploid perennial ryegrass / white clover sward compared with 13% for a late tetraploid perennial ryegrass / white clover sward under continuous sheep grazing.

White clover leaf size or the associated petiole length was shown to be highly significant in terms of white clover presence and persistence with the small leaved clover being superior in both respects (Spedding and Diekmahns, 1972, Williams *et al.*, 1982, Wilman and Asiegbu, 1982b, Charlton, 1984, Sedcole, 1985, Evans and Williams, 1987, Swift *et al.*, 1992a and Swift and Vipond, 1993). The very large leaved white clover was the poorest. This is not surprising with respect to the continuous, unrested sheep grazing treatment, as the small leaved white clovers produce a dense mass of branched stolons (Davies, 1970, Munro *et al.*, 1975, Baines *et al.*, 1983 and Frame and Newbould, 1986), which for the most part escape grazing. The very large leaved white clovers, on the other hand, tend to produce fewer, but often larger stolons with a minimum of branching, which are often grazed. Interesting interactions between clover leaf size and management treatment were observed and these will be discussed later.

One object of the inclusion of the grazing / rest management treatments was to test whether the incorporation of an appropriately timed rest, to allow a conservation cut, as suggested by Grant and Barthram (1990), had a beneficial effect on the white clover component of continuously sheep grazed perennial ryegrass / white clover swards. Curll and Wilkins (1985) likewise advocated a combination of cutting and grazing where stocking rates were so high as to threaten white clover survival and limit sheep performance. The other reason for the rest treatments was to determine most appropriate time for such a rest and to investigate any interactions with white clover or perennial ryegrass characteristics.

It is worth noting at this stage that "the end of first year" white clover percentage figures (figure 2.9) clearly show a greater percentage of white clover in the late rested sward than in the unrested sward. Nevertheless, there was greater number of white clover strikes and therefore a higher potential yield of white clover from the unrested treatment. These figures highlight the dangers associated with quoting "the percentage of white clover in a sward" as an indicator of the quantity of white clover production per unit area. Clearly however "percentage" figures have significance from an animal nutrition standpoint.

Figure 2.9 Perennial ryegrass / white clover quantities and white clover percentages at the end of the first treatment year - point quadrat data.



The results, then, indicated that during the first year when a particular grazing / rest management treatment was applied (figure 2.9), the quantity of white clover in the unrested sward treatment was greater than in any of the rested treatments. The greatest initial impact of the grazing / rest management treatments was on the perennial ryegrass sward component, where grass densities were greatest in the unrested swards and lowest in the later rested swards. The white clover therefore represented a greater proportion of the total herbage in the thinner, later rested swards than in the unrested or earlier rested swards. The effect of introducing a rest period, from continuous sheep grazing, in reducing perennial ryegrass tiller density was also noted by Grant and Barthram (1990).

By the second year of the management treatment these differences in the respective sward grass densities and the associated competitive pressure on the white clover influenced the sward white clover status. In the case of the unrested sward, there was a reduction in the presence of white clover, while the lower density of the later rested sward, coupled with this rest being at a time of peak white clover stolon development, enhanced the white clover status of the sward. Conversely, the aggressive early season growth from the perennial ryegrass in the early rested swards at a time of comparatively slow white clover growth, had an adverse effect on the sward white clover status. This agreed with the findings of Curll and Wilkins (1985) who found that high stocking rates, a rest in mid-season or later maintained the greatest sward white clover content and with Grant and Barthram (1990) who found greater white clover levels in later, albeit May / June, rested swards compared with April / May rested swards. It must be said however, that in their experiment, the use of very early perennial ryegrass for the early rest and late perennial ryegrass for the later rest made it difficult to isolate the effect of rest period from that of perennial ryegrass maturity group.

When the interaction between grazing / rest managements and white clover leaf size was taken into account, it was noted that management treatment had little impact on the presence records for small leaved white clover which remained high throughout. The adverse effect of the early rest on white clover presence was most severe with the very large leaved white clover. This was remarkable, in as much as, the principal virtue claimed for this group, is the competitive advantage afforded to them by their large leaves and long petioles when grown with grass for silage. The explanation of these responses is probably that the tall and vigourous grass growth associated with the early conservation rest encouraged a white clover growth habit where the larger leaved white clovers produce strong, non branching stolons which rose at an angle through the canopy rather than clinging to the ground surface. This resulted in a considerable amount of strong stolon and therefore of the plants reserves, being cut or left vulnerable to subsequent grazing. When rested during July to mid August grass heights were much lower allowing clover stolons to remain closer to the ground. Earlier grazing also encouraged a more branching type of growth at ground level. With white clover growth and development during this rest period being at its peak, a firm base of white clover was established.

While no significant interactions were observed between perennial ryegrass maturity group and grazing / rest managements, significant differences between individual treatments showed that the beneficial effects associated with later conservation rests were greatest and the harmful effects of early conservation rests were lowest, with very early and early varieties of perennial ryegrass. These trends may once again be attributed to competition pressure from perennial ryegrass. The rest during April to late May allowed the earlier perennial ryegrass varieties which were most aggressive during this period to have a large adverse effect on the white clover. The rest during mid to late summer, on the other hand, allowed white clover to develop in the more open sward associated with earlier varieties at a time when they were less aggressive and white clover growth was at its peak. The later varieties, which are inherently more dense offered maximum competition during this critical period.

Similarly, while no significant interaction was observed between perennial ryegrass ploidy and grazing / rest managements, it was noted that the adverse influence of an early rest and the favourable influence of the later rest were more pronounced in the case of diploid perennial ryegrass varieties. In both cases this was probably due to the more densely tillered habit of the diploid. With regard to the April to late May rest, it could be argued that the combined effect of the denser diploid sward and peak grass production at a time of slow white clover growth had a damaging effect on white clover development and survival. The later rest however, at a time of peak white clover growth, encouraged the diploid perennial ryegrass to adopt a more open growth habit which enhanced white clover development. The tetraploid was so open that any reduction in tiller production gave little assistance to white clover development.

2.10 CONCLUSIONS

1. Continuous stocking of perennial ryegrass / white clover swards with sheep does not necessarily have an adverse effect on the survival and / or maintenance of satisfactory levels of white clover in the sward.

2. An April to late May rest from continuous stocking with sheep reduced the sward white clover content in perennial ryegrass / white clover associations. This effect increased with increasing white clover leaf size.

3. A July to mid August rest from continuous stocking with sheep, increased the sward white clover content in perennial ryegrass / white clover associations. This effect increased with increasing white clover leaf size.

4. Any rest from continuous stocking with sheep on perennial ryegrass white clover swards reduced the perennial ryegrass density. This effect was greater with an April to late May rest than with a July to mid August rest.

5. Tetraploid perennial ryegrass / medium / large leaved white clover swards consistently contained more white clover than diploid perennial ryegrass / white clover swards.

6. Earlier perennial ryegrass / white clover swards generally contained more white clover than later perennial ryegrass / white clover associations.

7. Small leaved white clovers in perennial ryegrass / white clover associations were more persistent, and very large leaved white clovers were less persistent than medium or large leaved white clovers under the range of cutting and grazing managements tested.

CHAPTER 3

EXPERIMENT 1

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS:

2. CANOPY ARCHITECTURE

CHAPTER 3

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS: 2. CANOPY ARCHITECTURE

INTRODUCTION

The objective of imposing a rest from continuous stocking by sheep was primarily to investigate the effect and the influence of the timing of such a rest, on the "quantity" of white clover in different perennial ryegrass / white clover associations as reported in chapter 2. This however provided an excellent opportunity to investigate the effects of white clover leaf size, perennial ryegrass ploidy and maturity grouping, perennial ryegrass and white clover seasonal growth patterns and growth period along with any interactions on canopy architecture and white clover stolon and leaf development under both continuously stocked and rested managements.

3.1 CANOPY ARCHITECTURE - PROCEDURES AND ASSESSMENTS

The relative productivity and dynamics of different grass / white clover associations are influenced by the seasonality of various sward components and their respective positions within the sward canopy. With respect to the characteristics of the grass component in such swards, there is the potential for diversity of spatial preference / occupancy, from both specific and varietal origin, in terms of seasonality, ploidy, growth habit and response to management. White clover likewise displays considerable diversity of habit with regard to cultivar characteristic and response to defoliation. Rhodes (1981) described several non-destructive techniques for describing canopy structure. The preferred technique he proposed for characterising canopy structure using the point quadrat was to move the needles penetrating the canopy at a fixed angle to the perpendicular. He also described the destructive stratified clip technique using a variety of devices with or without vacuum equipment to collect the herbage from each horizon. Barthram (1992), described a simple plier-like instrument which could be used to sample foliage from a range of horizons for detailed examination and characterisation of canopy architecture and the type of foliage within each horizon. Unfortunately this device was developed too late to have been of use in this investigation.

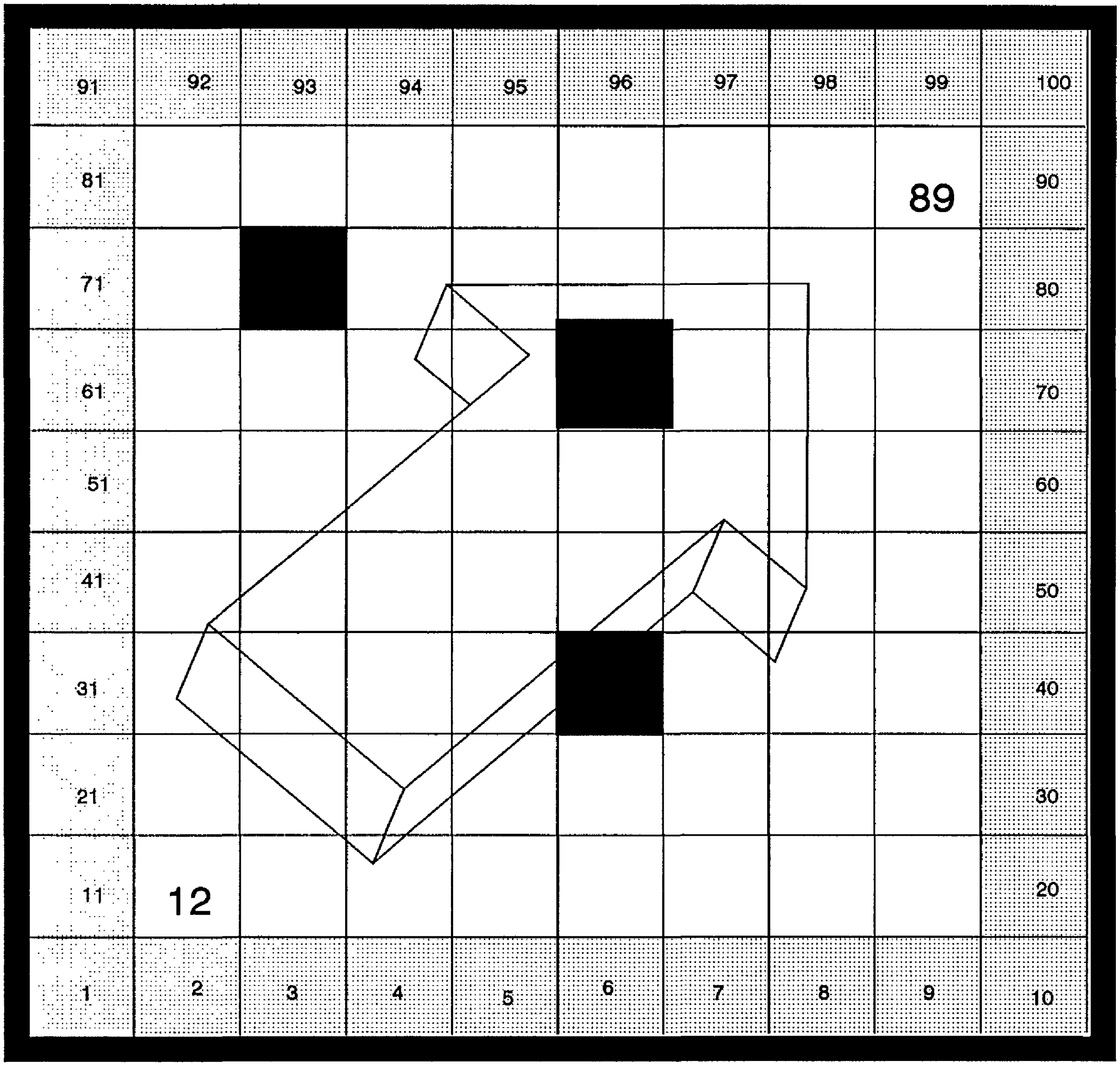
Although detailed measurements of canopy structure would have been very useful, they were not attempted in this experiment because of the size of the experiment in terms of the large number of plots which meant that it would have taken several weeks to complete "point quadrat" assessments. During this critical time of year the canopy would have changed to such an extent that any comparison between treatments would have been invalid and misleading.

The practical feasibility of making these measurements within the rested plots was also questioned, as the assessment was planned to describe canopy architecture in the rested / conservation plots just prior to the conservation cut which was scheduled for end of a six-week rest period (figure 2.2). A special non-standard point quadrat would have to have been constructed to accommodate the tall herbage at that stage of growth. The chance of strikes in the open upper layers of the canopy would have been very small and influenced by any slight breeze or other disturbance.

It was observed however that within the rested / conservation swards, the white clover leaves were positioned in a narrow band high in the canopy (Woledge *et al.*(1992a). It was possible therefore to make simple measurements using a metre stick. The day prior to the scheduled cutting date, the heights of both perennial ryegrass and white clover were measured using a meter stick. The metre stick was placed vertically through the canopy until it touched the ground. The average heights of both perennial ryegrass and white clover were then visually assessed. Five readings for perennial ryegrass and five for white clover were made at random in each plot. These perennial ryegrass and white clover height assessments were made prior to "first" and "third" cut treatments in the first treatment year.

Plate 3.1 Rested plots showing different canopy heights

Figure 3.1 "GRID" quadrat described opposite



3.2 WHITE CLOVER STOLON DEVELOPMENT

From the inception of the experiment it was the intention to make detailed measurements of clover stolon development. The following method was therefore developed to examine clover growth and development.

1. A $1m^2$ quadrat sub-divided into one hundred 10 cm x 10 cm squares was constructed which could be laid over a $1m^2$ plot.
2. Each square was numbered from left to right, with the nearest left hand corner as 1, and the opposite corner as 100.
3. A simple "basic" programme was written to generate sets of three random numbers between 12 and 89 omitting those which end with "0" or "1".
4. Three 10 cm x 10 cm quadrats were made, using brazing rods, and painted red to make them easily seen.
5. The $1m^2$ "grid quadrat" was laid directly over the plot to be assessed. Three squares from the grid were identified, using the appropriate random numbers, and the 10 cm x 10 cm quadrats were positioned in these squares. The $1m^2$ grid was then removed.
6. In each of the three squares in turn the number of grass tillers, number of white clover growth points and number of trifoliate leaves was recorded.
7. Within each of the three 10 cm x 10 cm squares a main stolon was selected. Starting at the apical growth point detailed measurements were made:

Folded (apical) lamina (length [mm] x 2) - mean of three quadrats

1st lamina (length x breadth [mm]) - mean of three quadrats

(repeat for each subsequent non senescing lamina or to a major stolon branch)

Folded (apical) leaf petiole length (mm) - mean of three quadrats

1st petiole length (mm)

(repeat for subsequent non senescing expanded leaf petioles or to a major stolon branch)

These assessments were conducted two weeks prior to conservation cuts in late May and early August on rested plots and on two replicates of grazed plots during July.

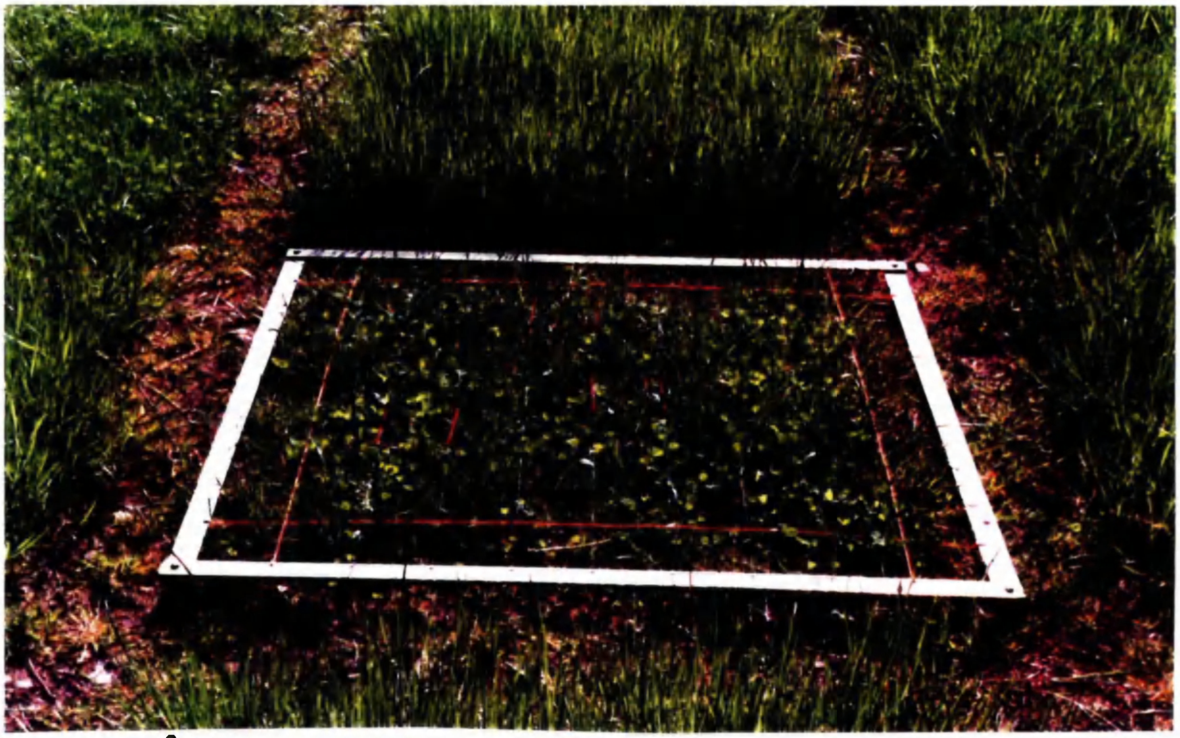
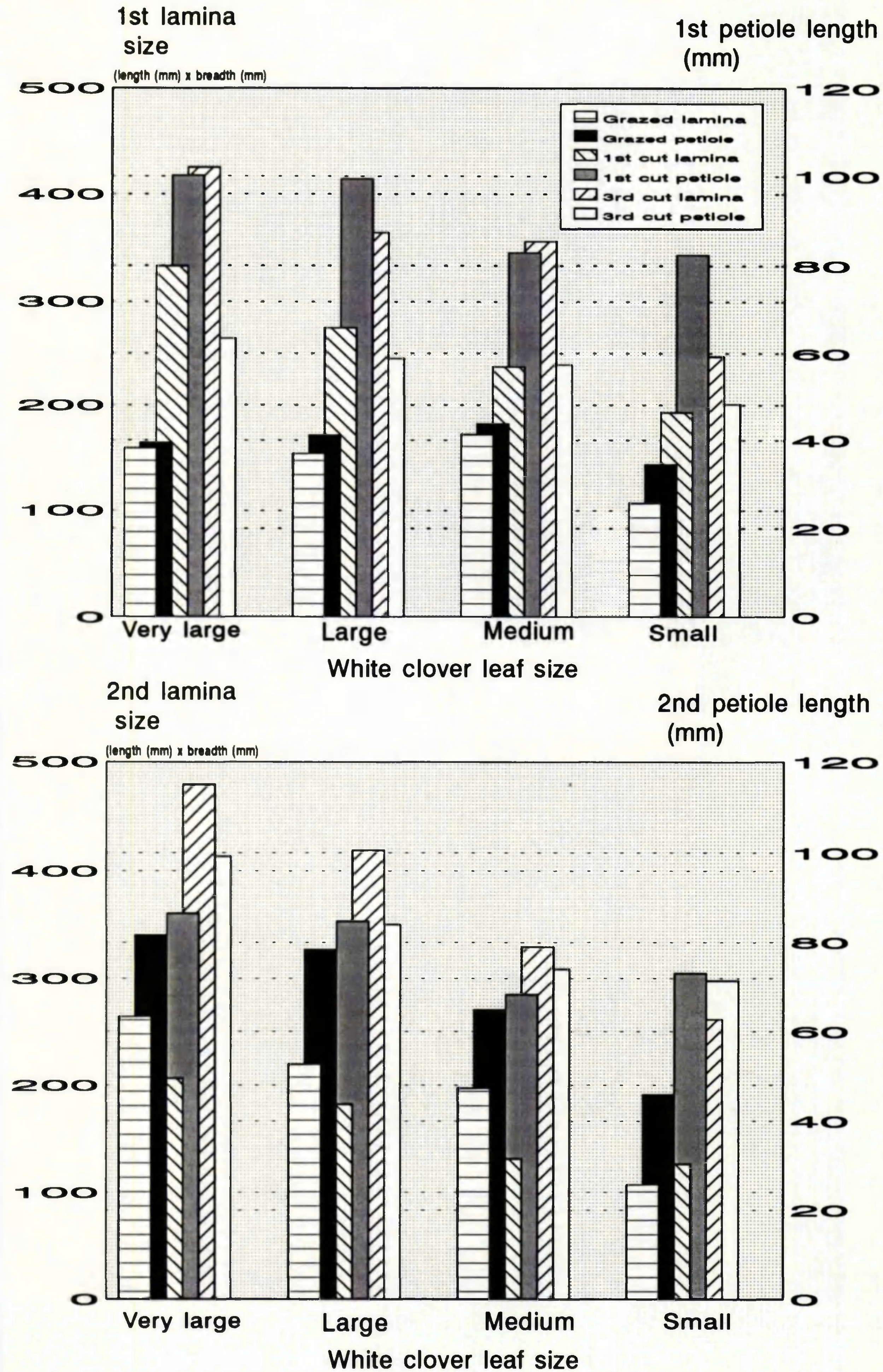


Plate 3.2 $1m^2$ Grid quadrat being used to locate and position random $3 \times 10000\ mm^2$ quadrats.

Plate 3.3 Detailed clover leaf and petiole measurements being made.

Figure 3.2 The effect of grazing / rest management on white clover lamina and petiole dimensions.



The measurements of canopy architecture and detailed grass and clover parameters were prepared using "Supercalc 5.1" and "Wordstar 6" and analysed by analysis of variance using "Genstat 5". Full tables of results for this section are presented in appendix 4.

3.3 RESULTS

3.3.1 The influence of white clover leaf size on canopy architecture and white clover morphology in grazed and rested perennial ryegrass / white clover swards.

Canopy height (measured immediately prior to cutting)

The type of white clover, in terms of leaf size had no significant effect on the standing height of perennial ryegrass or white clover either in the first or third cut treatments (figure 3.2; appendix 4 - tables 13.1, 13.2). While no trends were observed within the grass height data, the first cut data for white clover heights suggested a relationship between white clover leaf size and the position of the white clover leaf within the canopy. Very large leaved white clover's leaf heights were recorded at 251 mm, large at 239 mm, medium at 230 mm and small at 228 mm. At third cut the picture was less clear, albeit, the white clover leaf height values for very large and large leaved white clovers were higher than for medium and small leaved at 124 mm and 127 mm against 114 mm and 118 mm respectively. The differences in both cases were very small when taken in the context of overall height.

Petiole length (measured two weeks before cutting in rested plots)

The canopy height data was supported by detailed measurements of white clover petiole length with the petioles of the first and second leaves in the first cut sward (figure 3.2; appendix 4 - table 13.1) being significant at the 95% level while similar values for the first and second petioles at third cut were significant at the 95% and 99% levels respectively.

Leaf dimensions (measured two weeks before cutting in rested plots)

While differences white clover petiole length, although significant, were small, differences in white clover leaf size were highly significant and more pronounced in both first and third cut swards (figure 3.2; appendix 4 - tables 13.1, 13.2). The most dramatic

Figure 3.3 The effect of perennial ryegrass ploidy on grass and white clover height in silage crops.

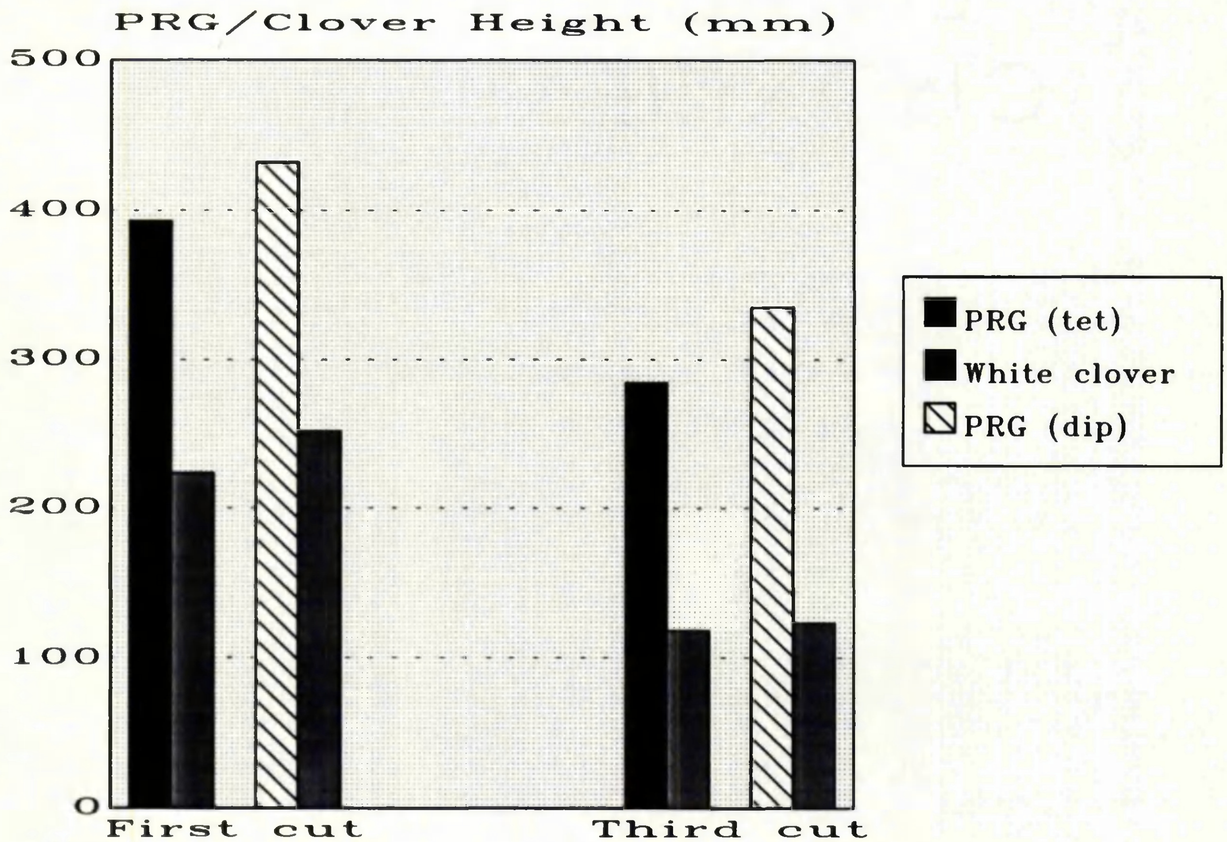
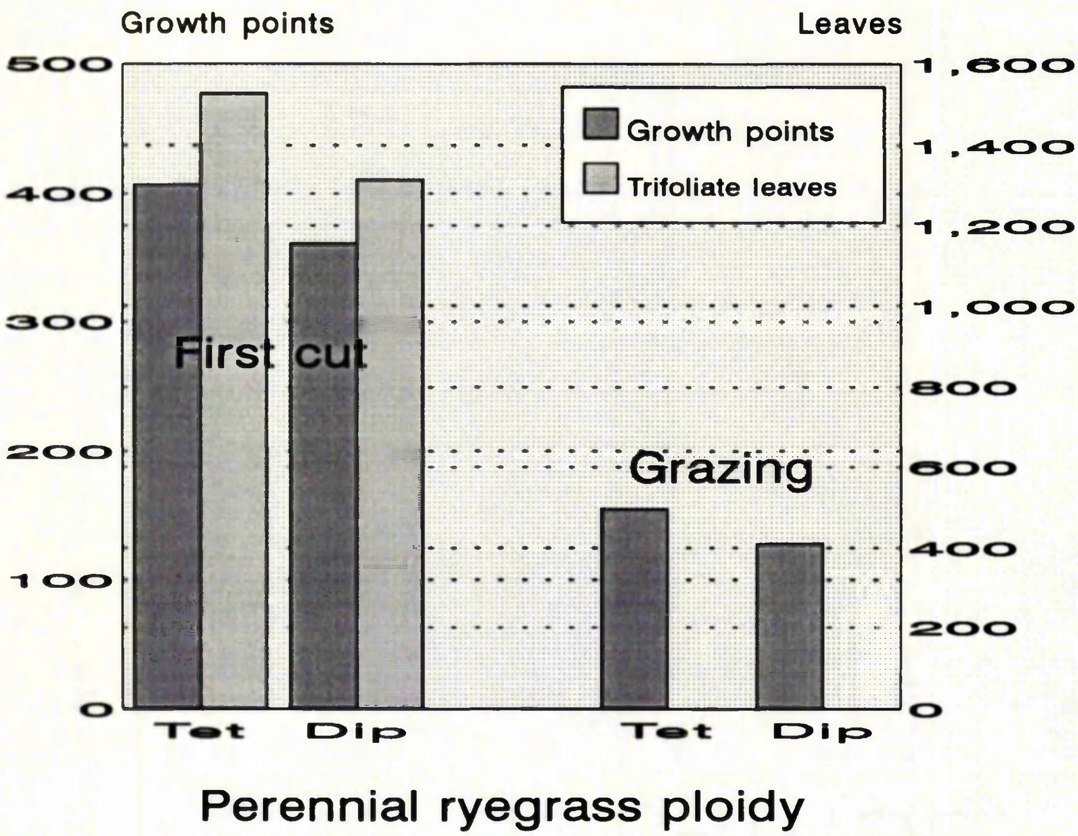


Figure 3.4 The effect of perennial ryegrass ploidy on white clover growth point and tri-foliate leaf number.



of these trends was the second expanded leaf in the first cut sward data with length (mm) x breadth (mm) values for very large leaved white clover of 206, large 182, medium 131 and small 126. Third expanded leaves at third cut from very large to small leaved varieties had values of 549, 336, 320 and 250 respectively. In the grazing situation (figure 3.2; appendix 4 - table 13.3), the same pronounced and highly significant trends were observed with the second expanded leaf and its petiole. However with other leaves the medium leaved white clovers had larger leaves and longer petioles. It was also noted that in all cases, white clover leaves in grazed swards were smaller and the shorter than in rested swards.

Growth points (measured two weeks before cutting in rested plots)
The number of white clover growth points per m^2 were also estimated for both grazed and first cut swards (figure 3.4; appendix 4 - tables 13.1, 13.3). These values showed highly significant trends in both cases. In the rested sward, values showed a trend from 228 and 284 for very large and large leaved to 425 and 600 for medium and small respectively. A similar trend was observed in the grazed sward, although the number of growth points was much smaller, ranging from 73 with the very large to 274 with the small.

Trifoliate leaves (measured two weeks before cutting in rested plots)
Likewise the number of trifoliate leaves per m^2 in the first cut rested treatment (figure 3.4; appendix 4 - table 13.1) was much greater with the small and medium leaved white clovers at 2377 and 1498 compared with the large and very large leaved clovers at 777 and 1036 respectively.

Sown grass tillers (measured two weeks before cutting in rested plots)
It was also noted, that in the first cut rested treatment, grass tiller numbers (per m^2) were significantly lower when grown with small and medium leaved white clovers with numbers of 2981 and 3022 compared with large and very large white leaved clovers at 3553 and 3296. This is most probably due to increased competition from the small and medium leaved white clovers as indicated by their associated growth point and trifoliate leaf numbers.

Figure 3.5 The effect of perennial ryegrass ploidy and management on white clover lamina size and petiole length.

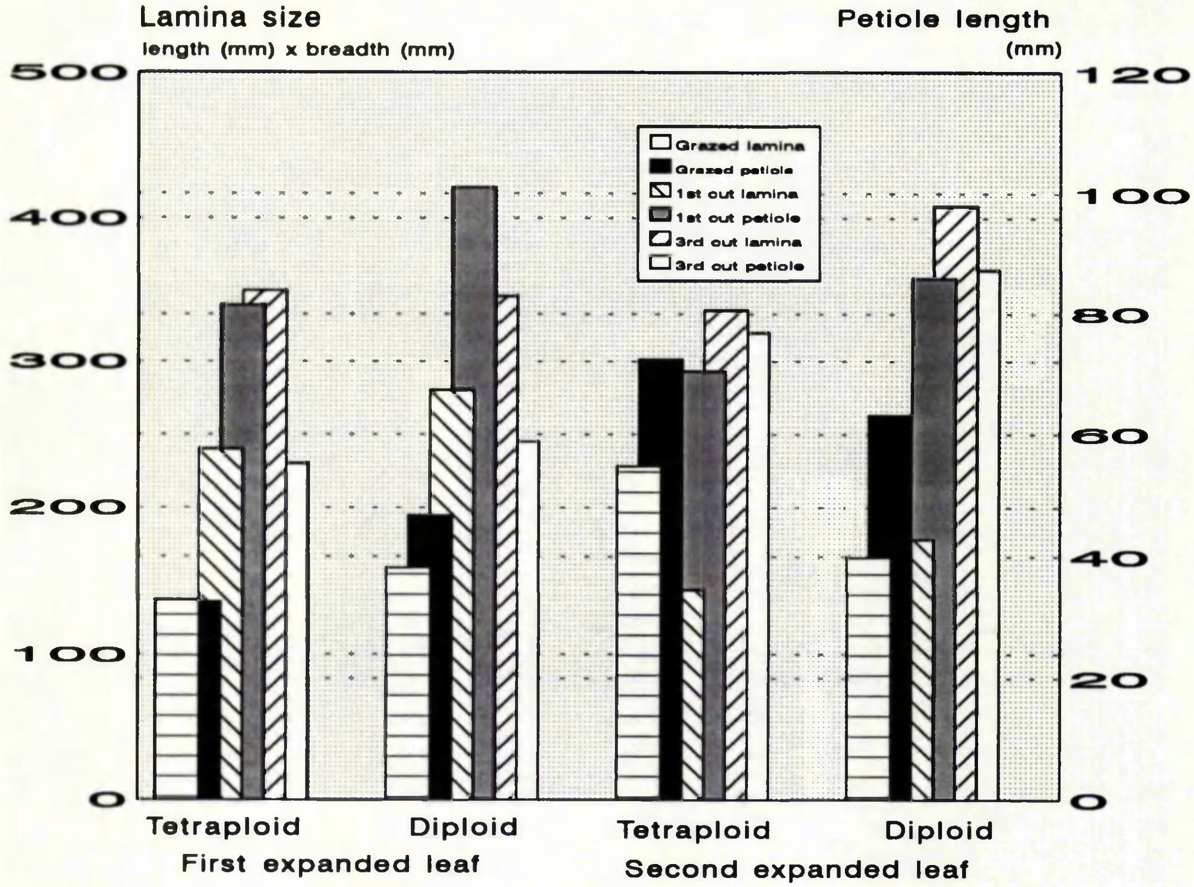
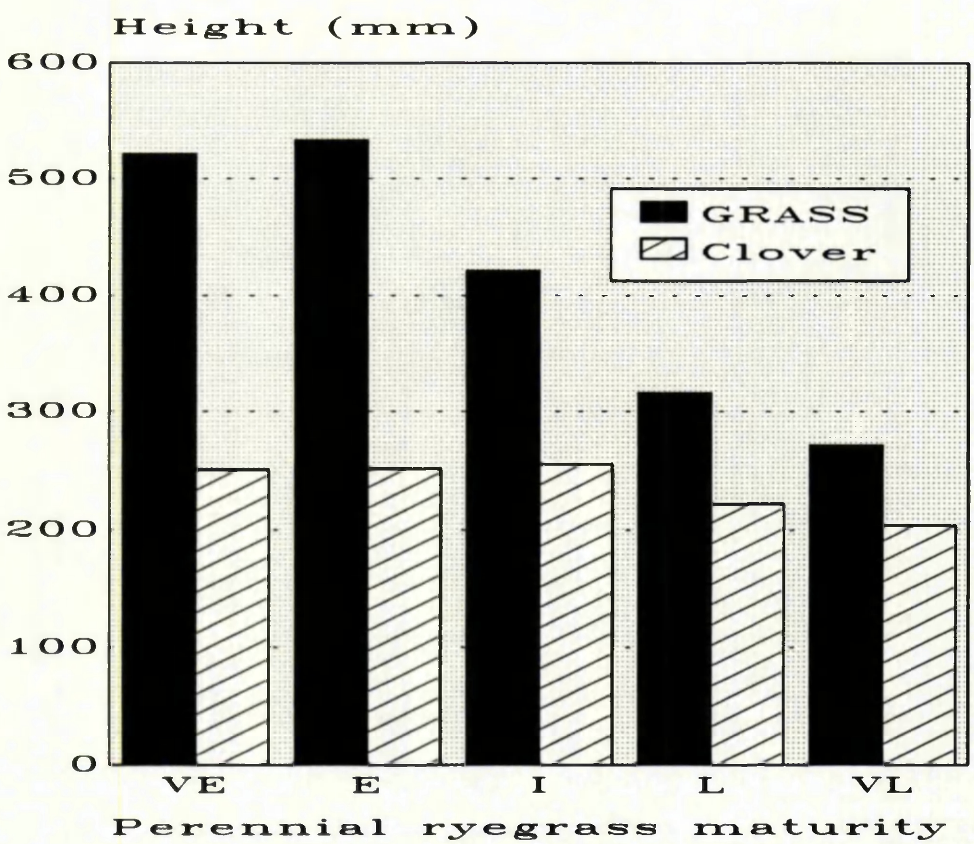


Figure 3.6 The effects of perennial ryegrass maturity group and corresponding grass heights after an April to late May rest on white clover heights.



3.3.2 The influence of perennial ryegrass ploidy on canopy architecture and white clover morphology in grazed and rested perennial ryegrass / white clover swards.

Grass height

Perennial ryegrass heights in both first and third cut treatments were significantly (at the 99% level) greater in diploid than with tetraploid associations with values of 393 mm for tetraploid and 432 mm for diploid at first cut and 284 against 335 for second cut respectively (figure 3.3; appendix 4 - tables 13.4, 13.5).

White clover height

The influence of greater heights and greater tiller density in the diploid perennial ryegrass / white clover association was reflected in greater white clover heights in the diploid swards than in the tetraploid perennial ryegrass / white clover association (figure 3.5). This difference in white clover heights was highly significant in the first cut swards with values of 223 mm for the tetraploid perennial ryegrass / white clover against 251 mm for the diploid perennial ryegrass / white clover association. These trends were consistently supported by all expanded leaf petiole measurements for both cuts. The greater clover height and petiole lengths associated with diploid perennial ryegrass / white clover associations was also accompanied by trends towards greater leaf size in diploid swards although these were only significant above the 95% level in first cut treatments.

Growth points and trifoliate leaves

This superiority of white clover dimensions within diploid perennial ryegrass / white clover associations did not extend to growth point and trifoliate leaf numbers. First cut sward records showed (figure 3.4; appendix 4 - table 13.4) white clover growth point numbers were higher in tetraploid perennial ryegrass / white clover associations than in diploid perennial ryegrass / white clover associations with 407 /m^2 in the tetraploid perennial ryegrass associations compared with 361 in the diploid. This was reflected in higher trifoliate leaf numbers in the tetraploid perennial ryegrass white clover association at 1529 /m^2 compared with 1314 in the diploid perennial ryegrass / white clover association. This general trend was also observed within the grazed swards (figure 3.4; appendix 4 - table 13.6). Growth point numbers were greater in the tetraploid perennial ryegrass / white clover associations at 155 /m^2 compared with 128 /m^2 in the diploid perennial ryegrass / white clover association. However no clear effect of perennial ryegrass ploidy was observed with regard to clover leaf size and petiole length in a continuous stocking situation.

3.3.3 The influence of perennial ryegrass maturity group on canopy architecture and white clover morphology in grazed and rested perennial ryegrass / white clover swards.

While the perennial ryegrass maturity group treatments were seen to be influenced by cutting and grazing management treatments it was difficult to identify any clear patterns (Figure 3.6; appendix 4 - tables 13.7, 13.8, 13.9). Within both first and third cut treatments, grass height was greater with earlier varieties and lower with later varieties. At first cut this was partially reflected in white clover heights with earlier and therefore taller perennial ryegrasses producing taller white clover companion heights. The number of perennial ryegrass tillers was significantly (at the 99.9% level) greater with later perennial ryegrass maturity groups than with earlier. Corresponding white clover growth point values tended to be greater with the earlier and very late perennial ryegrass associations. It must be said that the high growth point record in the very late associations may be due to the poor initial Bardetta establishment and would probably not have been maintained into a second year due to annual meadow grass infestation. Clear trends were not observed with regard to the effect of perennial ryegrass maturity group on white clover growth points numbers and leaf and petiole dimensions.

3.4 DISCUSSION

During consultations at the inception of this experiment it was suggested that white clover stolon development should be monitored under grazing conditions using marked stolons. Stolons had been successfully marked elsewhere in cattle grazing experiments using coloured wire or plastic "bird" rings. A similar technique was adopted and described by Chapman (1983) using coloured plastic tubing and colour coded steel staples. It was decided therefore, to mark stolons using plastic rings at the beginning of the season and to measure stolon growth, leaf number and size, branching and development of growth points under different management regimes at regular intervals throughout the season. Three stolons per plot were marked, at random, in this way. It was soon realised however that with close grazing with sheep a moderate proportion of the stolon was grazed (Curll and Wilkins, 1982, Clark *et al.*, 1984 and Evans *et al.*, 1992). and the marker rings were either loosened by treading or grazing or ingested and consequently scattered over the trial area, loose or in faeces. It soon became evident that, even if this technique had been successful, the large number of plots coupled with the time spent in frequent stolon and other measurements and time spent remarking with successive colour coded staples would have rendered it impracticable. The technique of marking stolons was therefore abandoned for this situation. Chapman (1983) gave no details of his target sward surface height but it was likely that grazing pressure was less severe in this trial so that less actual stolon grazing probably occurred. He also used a metal frame erected over marked stolons to protect them from treading at certain times of year.

The technique using random 100 mm^2 quadrats was developed and used to make some detailed measurements of stolon development in both rested and grazed plots.

It is pertinent when considering the results presented in the previous section, that at the time of the assessments, not all the grazing / rest treatments had been applied and that the measurements were made at different growth stages and at different times of year. In effect, the forty perennial ryegrass / white clover associations were being sampled:

. pre cutting in late May

. pre cutting in early August

. continuously stocked in July

Many of the measurements made exhibited trends which could have been anticipated. It was nevertheless valid to confirm such predictions and in so doing a number of interesting and unexpected observations were made. For example, earlier perennial ryegrasses had taller grass heights than later perennial ryegrasses. This was attributed to relative maturity of the earlier grasses at the time of the assessment. However, the earlier and therefore taller perennial ryegrasses evoked a complementary response from the companion white clover leading to taller white clover heights in these associations. A similar response in petiole length to increased canopy height was observed by Wilman and Shrestha (1985).

In general white clover heights (petiole lengths) within rested swards, predictably, increased with increasing white clover leaf size category, although the differences in height between the leaf size categories was comparatively small. This is in agreement with the results of work by Woledge *et al.* (1992a) who found leaflets of both small and large leaved white clover types in the uppermost layers of the canopy, receiving good light, even at a sward height of 400 mm. Much greater differences were demonstrated between white clover leaf size categories and measured leaf size. Predictably these were in accord with the leaf size groupings.

It was mentioned in chapter 2 that, under continuous stocking, differences between the leaf size of white clovers of different leaf size categories were minimal and that both leaf size and petiole lengths were reduced compared with the situation in rested swards. Measurements of the first fully opened (expanded) lamina on randomly selected stolons showed that differences in leaflet size between the four size categories were very small with significant differences between the medium and small leaved categories only. No significant differences were noted for petiole length between the groups. Measurements of second expanded leaves showed significant differences for both petiole length and petiole size. However it was observed that lamina size and petiole lengths within grazed swards were much smaller than for rested swards (table 3.1).

Table 3.1 White clover leaflet size in grazed swards as a percentage of white clover leaf size in rested swards.

	Measured white clover leaf size (grazed (July) as percentage of rested)	
	May rested	August rested
1st expanded leaflet	58	43
2nd expanded leaflet	121	52

This phenomenon was also observed by Korte and Parsons (1984) when they examined large leaved white clover under hard grazing and noted that it adopted a smaller leaved, more prostrate growth habit. Conversely, Curll and Wilkins (1985) observed that when rested from continuous stocking, white clover stolon length, petiole length and leaflet diameter increased though leaf and node number per unit length of stolon decreased. As above, they also noted that the reversed trend applied when the sward was returned to grazing after cutting.

It was also noted that while both petiole length and leaflet size reacted to canopy height and grazing / rest strategy, that there was an overall tendency, that as the season progressed, each sequential leaflet to develop, reached greater final dimensions than the previous leaflet to develop.

Growth point numbers (potential branches) and associated trifoliate leaf numbers were much greater with small and medium leaved white clovers compared with the larger leaved types. Both growth point numbers and trifoliate leaf numbers were much lower in continuously stocked, than in rested swards. Jones and Davies (1988) made similar observations and noted that under continuous stocking by sheep, white clover stolons carried, on average, between zero to two leaves per growth point. They also recorded (Davies and Jones, 1988) that when rested from continuous sheep grazing for a short period in mid summer, both the rate of white clover stolon growth point initiation and the rate of trifoliate leaf production, increased. Similarly, Laidlaw (1991) noted that growing point density is reduced by grazing and is sensitive to stocking intensity. Jones and Davies (1988) also observed that the carbohydrate content of the white clover stolons was reduced by hard grazing. From these combined effects it follows that hard continuous stocking limits white clover branching and depletes its carbohydrate reserves and thus moves the balance of species in the perennial ryegrass / white clover sward in favour of the grass. In theory at least it may be possible to achieve greater long term stocking rates with perennial ryegrass / white clover swards by maintaining taller sward surface heights than those currently recommended for grass only swards, thereby achieving a more open sward in terms of grass tiller numbers and a stronger, more branched white clover stolon network.

Surprisingly, grass height measurements in diploid perennial ryegrass / white clover swards were greater than in tetraploid perennial ryegrass / white clover swards. It may be surmised that this resulted from greater competition for light within the diploid perennial ryegrass / white clover sward. This same general trend was reflected both in greater white clover heights and greater white clover leaf sizes in the diploid perennial ryegrass / white clover swards (figures 3.3 and 3.6). This is again, at least partly, in keeping with the observations of Wilman and Shrestha (1985), that white clover adapted to tallness of canopy with increased petiole length rather than by an increase in leaflet size. This increase in petiole length and leaflet size however, was offset by competition for space with the more densely tillered diploid perennial ryegrass, giving lower growth point numbers (figure 3.4) than in the tetraploid perennial ryegrass / white clover sward. In the absence of any competition for light, as in the grazed sward, no clear pattern was observed between clover leaf size and ploidy.

Another surprising observation was that perennial ryegrass tiller numbers were influenced by competition from the white clover. Here perennial ryegrass tiller numbers were found to be lower with small and medium size leaved white clovers which with their greater number of growth points and trifoliate leaves competed more successfully than the large and very large leaved types.

3.5 CONCLUSIONS

CONSERVATION SWARDS

1. White clover heights (petiole lengths) increased with white clover leaf size categories, although differences were very small (only 23 mm between small and very large leaved groups).

2. White clover lamina size (length x breadth) increased with leaf size category with very large leaves about twice the size of small leaves.

3. Growth point numbers in small and medium leaved white clovers were two to three times greater than for the large and very large leaved types.

4. Trifoliate leaf number for small and medium leaved white clovers was two to three times greater than for the large and very large leaved types.

5. Perennial ryegrass tiller numbers were lower with small and medium leaved white clovers than with large and very large leaved white clovers.

6. Diploid perennial ryegrass heights were greater than tetraploid perennial ryegrass heights probably induced by greater intra-specific competition.

7. White clover heights were greater in association with diploid perennial ryegrass than with tetraploid perennial ryegrass.

8. Earlier perennial ryegrasses had taller grass heights at the time of measurement than later perennial ryegrasses (at least partly due to maturity at cutting) and this was reflected in greater white clover heights in earlier perennial ryegrass / white clover associations.

9. White clover leaf size became progressively greater as the season progressed up to mid August.

GRAZED SWARDS

1. White clover leaf size increases with leaf size category although leaves were smaller and petioles shorter in grazed compared with rested swards.

2. Newer trifoliate leaves tended to be larger than older leaves although this impression may have been due to the grazing of larger (older) leaves.

3. The number of growth points (and consequently the number of trifoliate leaves) was considerably smaller in the grazed compared with the rested swards.

4. No clear pattern was observed between clover leaf size and ploidy in the grazed situation.

CHAPTER 4

EXPERIMENT 1

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS:

3. CONSERVATION CUTS

CHAPTER 4

CUTTING AND GRAZING SYSTEMS FOR PERENNIAL RYEGRASS / WHITE CLOVER ASSOCIATIONS: 3. CONSERVATION CUTS

INTRODUCTION

As stated at the beginning of chapter 3, the object of having conservation (silage cut) treatments included in the experiment was to investigate the influence of the rest and its timing on the white clover contents of perennial ryegrass / white clover swards. This did however provide an opportunity to investigate the performance of the different associations with regard to their conservation yields and the relative contribution to yield of the sward components during the respective rest periods. The "rest" periods were selected to represent cuts taken at first, second and third cut times under a high quality silage regime. First cut was scheduled for late May with subsequent cuts to be taken at six-week intervals. It must be emphasised the cuts taken in early July and mid to late August were not in fact second and third cuts, but first cuts taken at second and third cut times after continuous stocking. If the measurement of conservation yields had been the over-riding purpose of the rest treatments it would have been appropriate to cut perennial ryegrass associations of different maturity groups on different occasions at the desired maturity stage (e.g. date of 50% ear emergence minus ten days). It was considered however that the long term sward effects were to get priority. This being the case, it was decided that, as the weather pattern between cuts could influence yield and the balance of sward components and that as different first cut dates would have implications on subsequent cuts and rest period duration, all associations should be cut at the same times.

4.1 CONSERVATION CUTS - EXPERIMENTAL PROCEDURES

First thing on the morning of the cutting day, the sheep were removed from the grazed plots and enclosed within the buffer area while the electric fences round the exclosures dismantled. The plots were the cut using a "Sheen Powascythe" cutting machine with a 78 cm blade. This allowed a small discard on either side of the plot, thus reducing the influence of edge effect. Discards, however, were not possible on the other two sides of the plot due to difficulties with the lie of the crop and lowering the cutter bar. The herbage was cut to a height of 30 mm - 40 mm from the ground. The herbage from the cut plots was immediately bagged using large polythene bags, weighed using a tripod with tared balance and the fresh weight recorded. The herbage was then emptied back on the plot immediately and two sub samples taken, one for botanical analyses, and one for dry matter determination.

Estimates of the percentage of the sward components in the total herbage dry matter were assessed by the following stylized method:

1. a known area of sward was cut;
2. the fresh weight of the herbage was recorded;
3. two sub samples of the cut herbage were taken - one for dry matter determination, the other for botanical analysis;
4. the dry weight of each sward component as a percentage of the total herbage dry weight was calculated using the total fresh weight, the total dry matter percentage and the dry weight of the individual sward components from botanical analysis.

The system used throughout the investigations reported in this thesis is the system generally adopted by SAC for National List and other trials. A sample of cut herbage (ideally a minimum of about 300 g) was netted in a standard polypropylene net bag (Netlon Ltd., "Minimesh" No. 10, as used for packaging fresh vegetables) and marked with a standard weight label. All the netted cut samples are quickly put together into a large polythene bag (several of these were required for this experiment) and tied, immediately transported to the laboratory where they were weighed and placed in wire mesh based trays. The weights were automatically recorded by computer on tape. The trays were put into a force draught oven, maintained at 104°C and dried overnight. The dried samples were weighed the following morning, the dry matter percentage automatically calculated and a print-out produced.

Samples taken for botanical analysis were put into numbered polythene bags, with the mouth tucked in to retain the herbage and the bags put together into a large polythene bag and placed in a cold store (maintained at 4°C) until analysis. The size of the sample taken depends on the length of the herbage and the complexity of the sward composition but was usually between 150 g and 500 g. Botanical analysis was carried out on a bench top and involved separating the sample of mixed herbage into the component species. Once separated the component fractions were dried in an oven and the dry weights recorded. The fresh weight, dry matter percentage and dry weights of the component species were used to calculate the percentage composition of the sward on a dry matter basis.

Botanical analyses for the second treatment year included a weed category which included broad leaved weeds and annual meadow grass. In due course the yield, dry matter and botanical analysis data were processed using "Supercalc 5.1" and "Wordstar 6" and analysed by analysis of variance using "Genstat 5".

Once the cutting procedure was completed, the small discards on either side of individual plots were be cut and the surplus cut grass raked to the discard area round the perimeter of the trial. At times of drought, the discard areas around the rested blocks were left uncut for the sheep to graze and thus avoid any severe grazing of newly released pasture. The electrified sheep netting fences were then re-erected round the subsequent rest area or removed completely after the third rest period. The water provision was moved if necessary. The sheep were then released from the buffer area and given access to the plots. Initially they ate the cut grass in the discard areas until full. Any remaining cut herbage was then removed or given to the sheep in the buffer area. After a few days sheep grazed the cut plots and the growth habit of the white clover reverted to a grazed habit of growth.

4.2 EXPERIMENTAL DETAILS

During the 1988 treatment year the experiment proceeded according to plan until the day before the planned third cut. At this stage the electric fencing unit was switched off (more likely as a student prank rather than sabotage) and by the time it was discovered, sheep had broken into two out the three conservation cut exclosures. Within these two blocks sufficient of the rested herbage had been grazed to make any attempt to assess

Table 4.1 - The effects of white clover leaf size and of rest timing on total yields (kg DM/ha) at conservation cuts.

1988

Rest period	White clover leaf size				SED	F pr.
	VL	L	M	S		
April-Late May	3954	3786	3912	4122	250.2 (198.3)	0.346
Late May & June	1868	1942	2074	2547		
July-Mid August	966	1336	1140	1831	310.3	0.721

1989

Rest period	VL	L	M	S	SED	F pr.
April-Late May	2279	2228	2022	2356	308.5 (147.5)	<0.001
Late May & June	882	1132	1044	2625		
July-Mid August	792	1008	928	1377		

() SED values in brackets are for the same level of rest.

sward yields or composition by botanical analyses, invalid. At third cut therefore only one replicate was harvested with yields and botanical composition being assessed and analysed. When the conservation results were analysed for the first harvest year, full data for first and second cuts were analysed together and then in a separate analysis data for replicate one for first, second and third cuts were analysed together. Once the "break in" was discovered, the sheep were removed to the buffer area, the electric fencing was dismantled for that year and grazing proceeded as planned. Although no yield measurements were made, the two aborted blocks were cut so that the plots involved were unaffected by the "break in". Sheep were returned to graze the whole area immediately the third cut was completed.

4.3 RESULTS

4.3.1 The influence of white clover leaf size

Total dry matter yields (table 4.1) demonstrate that in all cuts over both harvest years, perennial ryegrass associations with small leaved white clovers gave higher yields that with any other leaf size white clover companion. It was worthy of special note that this occurred even during the first harvest year before the effects of prolonged sheep grazing had time to modify the white clover growth habit.

Table 4.2 - The effect of white clover leaf size on yields and yield components at conservation cuts.

Dry Matter	White clover leaf size				SED	F pr.
	Very large	Large	Medium	Small		
1988 April - late May rest						
grass kg/ha	3343	3399	3190	3358	140.4	0.736
clover kg/ha	611	387	722	764	109.6	0.004
total kg/ha	3954	3786	3912	4122	233.0	<0.001
% clover	16.97	11.60	20.04	20.51	2.359	<0.001
1988 late May & June rest						
grass kg/ha	1445	1475	1381	1358	144.1	0.828
clover kg/ha	423	446	693	1189	89.4	<0.001
total kg/ha	1868	1942	2074	2547	160.5	<0.001
% clover	24.1	25.3	35.0	47.6	3.43	<0.001
1988 July - mid August rest						
grass kg/ha	398	417	425	641	100.2	0.101
clover kg/ha	568	919	715	1190	242.9	0.112
total kg/ha	966	1336	1140	1831	321.9	0.093
% clover	58.1	66.3	62.1	65.9	4.40	0.263
1989 April - late May rest						
grass kg/ha	2136	2077	1901	1957	141.8	0.332
clover kg/ha	15	562	457	295	26.13	<0.001
weed kg/ha	128	95	76	104	24.74	0.219
total kg/ha	2279	2228	2022	2356	144.4	0.127
% clover	0.87	3.32	2.53	14.66	1.504	<0.001
1989 late May & June rest						
grass kg/ha	745	839	800	828	107.5	0.821
clover kg/ha	56	232	180	1734	105.0	<0.001
weed kg/ha	82	62	65	64	26.36	0.858
total kg/ha	882	1132	1044	2625	145.0	<0.001
% clover	7.0	22.3	17.1	65.8	3.53	<0.001
1989 July - mid August rest						
grass kg/ha	591	574	659	726	106.7	0.473
clover kg/ha	165	408	218	633	91.0	<0.001
weed kg/ha	35.8	22.9	50.9	18.5	10.61	0.014
total kg/ha	792	1008	928	1377	158.1	0.003
% clover	19.4	30.1	21.7	43.5	4.45	<0.001

Table 4.3 - The effects of white clover leaf size and of rest timing on white clover dry matter yields as a percentage total dry matter yields at conservation cuts.

1988

Rest period	White clover leaf size				SED	F pr.
	Very large	Large	Medium	Small		
April-Late May	16.97	11.60	20.04	20.51	8.204 (2.904)	<.001
Late May & June	24.09	25.26	34.95	47.56		
July-Mid August	58.12	66.29	62.12	65.89	4.628	0.034

1989

Rest period	Very large	Large	Medium	Small	SED	F pr.
April-Late May	0.87	3.32	2.53	14.66	5.281 (3.443)	<.001
Late May & June	7.02	22.25	17.13	65.75		
July-Mid August	19.41	30.13	21.72	43.51		

() SED values in brackets are for the same level of rest.

The effects of white clover leaf size on the components of yield (table 4.2) however show that differences in yield between the different white clover leaf size / perennial ryegrass associations can be attributed largely to the differences in the white clover dry matter contribution rather than to differences in perennial ryegrass yields where no significant differences were observed. The clover dry matter yields taken as a percentage of total dry matter yields (table 4.3) show very clear trends in which clover percentages increase with later cuts and smallness of leaf size.

4.3.2 The influence of perennial ryegrass ploidy.

Total dry matter yields (table 4.5) showed no consistent effect from perennial ryegrass ploidy over all cuts. However, in both harvest years, the diploid perennial ryegrass / white clover associations gave slightly higher yields than tetraploids perennial ryegrass / white clover associations at first cut. No clear pattern emerged at subsequent cuts.

Table 4.4 - The effect of perennial ryegrass ploidy on yields and yield components at conservation cuts.

Dry Matter	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
1988 April - late May rest				
grass kg/ha	3009	3636	140.1	<0.001
clover kg/ha	600	642	77.5	0.586
total kg/ha	3609	4279	164.8	<0.001
% clover	17.42	17.14	1.668	0.867
1988 late May & June rest				
grass kg/ha	1368	1462	99.9	0.348
clover kg/ha	712	673	63.2	0.541
total kg/ha	2080	2136	113.5	0.626
% clover	34.3	31.6	2.42	0.275
1988 July - mid August rest				
grass kg/ha	467	473	70.9	0.934
clover kg/ha	858	838	171.8	0.909
total kg/ha	1325	1311	227.6	0.951
% clover	64.2	62.0	3.11	0.482
1989 April - late May rest				
grass kg/ha	1898	2138	100.2	0.019
clover kg/ha	127	78	18.48	0.011
weed kg/ha	99	103	17.49	0.821
total kg/ha	2123	2319	102.1	0.058
% clover	6.19	4.50	1.063	0.117
1989 late May & June rest				
grass kg/ha	850	756	76.0	0.220
clover kg/ha	570	531	74.2	0.601
weed kg/ha	65	71	18.64	0.742
total kg/ha	1484	1358	102.5	0.220
% clover	29.4	26.7	2.50	0.271
1989 July - mid August rest				
grass kg/ha	606	669	75.4	0.404
clover kg/ha	347	365	64.3	0.777
weed kg/ha	37	27	7.5	0.220
total kg/ha	991	1062	111.8	0.530
% clover	28.1	29.3	3.15	0.716

Table 4.5 - The effects of perennial ryegrass ploidy and of rest timing on total yields (kg DM/ha) at conservation cuts.

1988

Rest period	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
April-Late May	3609	4279	207.2 (140.2)	0.002
Late May & June	2080	2136		
July-Mid August	1325	1311	219.4	0.041
1989				
April-Late May	2123	2319	290.3 (104.3)	0.09
Late May & June	1484	1358		
July-Mid August	991	1062		

() SED values in brackets are for the same level of rest.

Results showing the components of yield (table 4.4) show slightly higher clover percentages in the tetraploid perennial ryegrass / white clover associations although this could be attributed mainly to lower grass yields from tetraploid perennial ryegrass / white clover associations especially in the first harvest year.

Table 4.6 - The effects of perennial ryegrass ploidy and of rest timing on white clover dry matter as a percentage of total dry matter yields at conservation cuts.

1988

Rest period	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
April-Late May	17.42	17.14	7.943 (2.053)	0.413
Late May & June	34.3	31.63		
July-Mid August	64.23	61.97	3.272	0.779
1989				
April-Late May	6.19	4.5	4.686 (2.435)	0.502
Late May & June	29.42	26.65		
July-Mid August	28.12	29.27		

() SED values in brackets are for the same level of rest.

Table 4.7 - The effect of perennial ryegrass maturity groups on yields and yield components (kg DM/ha) at conservation cuts.

Dry Matter	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
1988 April - late May rest							
grass kg/ha	3998	4331	3759	2805	1719	222.0	<0.001
clover kg/ha	513	615	492	592	894	122.5	0.012
total kg/ha	4511	4946	4251	3397	2613	260.5	<0.001
% clover	11.46	12.69	11.79	12.32	33.15	2.637	<0.001
1988 late May & June rest							
grass kg/ha	1606	1469	1440	1270	1290	158.0	0.200
clover kg/ha	692	671	755	634	713	99.9	0.799
total kg/ha	2298	2140	2195	1903	2003	113.5	0.206
% clover	31.6	32.0	34.0	32.2	34.9	3.83	0.888
1988 July - mid August rest							
grass kg/ha	509	353	379	552	558	112.1	0.101
clover kg/ha	783	666	1122	968	701	271.6	0.441
total kg/ha	1292	1019	1502	1520	1259	359.9	0.638
% clover	59.2	65.5	70.9	63.2	56.7	4.92	0.093
1989 April - late May rest							
grass kg/ha	2274	2738	2177	1643	1258	158.5	<0.001
clover kg/ha	118	140	85	71	98	29.22	0.141
weed kg/ha	111	94	111	97	90	27.66	0.914
total kg/ha	2504	2972	2372	1811	1446	161.4	<0.001
% clover	5.09	4.68	4.17	4.33	8.46	1.681	0.073
late May & June rest							
grass kg/ha	629	704	828	862	990	120.2	0.035
clover kg/ha	581	602	674	422	473	117.4	0.210
weed kg/ha	93	94	71	34	50	29.47	0.172
total kg/ha	1303	1401	1573	1317	1512	162.1	0.375
% clover	32.9	31.5	31.5	22.2	22.0	3.95	0.007
1989 July - mid August rest							
grass kg/ha	756	581	537	553	761	119.3	0.147
clover kg/ha	473	328	303	368	307	101.7	0.438
weed kg/ha	35	34	38	20	33	11.86	0.582
total kg/ha	1264	943	878	946	1101	176.8	0.193
% clover	31.8	30.4	29.6	28.1	23.7	4.98	0.549

4.3.3 The influence of perennial ryegrass maturity group.

As might be expected, very early, early and intermediate perennial ryegrass / white clover associations gave higher total dry matter yields at first cut than later associations. These trends were also reflected in the mean yields of total dry matter (table 4.8).

Table 4.8 - The effects of perennial ryegrass maturity and of rest timing on total yields (kg DM/ha) for conservation cuts.

Rest period	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
1988							
April-Late May	4511	4946	4251	3397	2631	269.1 (221.7)	<.001
Late May & June	2297	2140	2195	1903	2003		
July-Mid August	1292	1019	1502	1520	1259	347	<.001
1989							
April-Late May	2504	2972	2372	1811	1446	317.2 (164.9)	<.001
Late May & June	1303	1401	1573	1317	1512		
July-Mid August	1264	934	878	946	1101		

() SED values in brackets are for the same level of rest.

However, no clear pattern was observed for second and third cuts. Table 4.7 illustrates that during the first harvest year there was a consistent and highly significant trend with white clover percentages increasing with lateness of perennial ryegrass maturity. This trend however was just as clearly reversed during the second harvest year. This trend is supported when the effects of perennial ryegrass maturity group on white clover percentages are examined on a first, second and third cut basis (table 4.9).

Table 4.9 - The effects of perennial ryegrass maturity and of rest timing on white clover dry matter yield as a percentage of total dry matter yields at conservation cuts.

<table>
<tr><th colspan="8">1988</th></tr>
<tr><th rowspan="2">Rest period</th><th colspan="5">Perennial ryegrass maturity group</th><th rowspan="2">SED</th><th rowspan="2">F pr.</th></tr>
<tr><th>VE</th><th>E</th><th>I</th><th>L</th><th>VL</th></tr>
<tr><td>April-Late May</td><td>11.46</td><td>12.69</td><td>11.79</td><td>17.32</td><td>33.15</td><td rowspan="2">8.331
(3.25)</td><td rowspan="2"><.001</td></tr>
<tr><td>Late May & June</td><td>31.58</td><td>32.05</td><td>34.05</td><td>32.23</td><td>34.93</td></tr>
<tr><td>July-Mid August</td><td>59.18</td><td>65.52</td><td>70.95</td><td>63.18</td><td>56.69</td><td>5.174</td><td>0.002</td></tr>
<tr><th colspan="8">1989</th></tr>
<tr><td>April-Late May</td><td>5.09</td><td>4.68</td><td>4.17</td><td>4.33</td><td>8.46</td><td rowspan="3">5.554
(3.85)</td><td rowspan="3">0.103</td></tr>
<tr><td>Late May & June</td><td>32.93</td><td>31.51</td><td>31.5</td><td>22.22</td><td>22.03</td></tr>
<tr><td>July-Mid August</td><td>31.75</td><td>30.35</td><td>29.57</td><td>28.08</td><td>23.7</td></tr>
</table>

() SED values in brackets are for the same level of rest.

These results show that in both years, first cut white clover percentages were greatest with very late varieties. By the second year however, white clover percentages in both second and third cuts showed consistently higher white clover levels with earliness of perennial ryegrass maturity group.

4.3.4 The effect of rest timing on yield & yield components for conservation cuts.

Table 4.10 The effect of rest timing on yields and yield components for conservation cuts.

1988

Dry Matter	Rest for conservation cut			SED	F pr.
	April-Late May	Late May & June	July-Mid August		
grass kg/ha	3322	1415	470	285.8†	0.022†
clover kg/ha	621	693	848	124.5†	0.623†
total kg/ha	3944	2108	1318	182.0†	0.010†
% clover	17.3	33	63.1	7.809†	0.182†
1989					
grass kg/ha	2018	803	638	241.0	0.009
clover kg/ha	102	550	356	90.1	0.019
weed kg/ha	101	68	32	27.64	0.154
total kg/ha	2221	1421	1026	280.8	0.031
% clover	5.4	28.0	28.7	4.358	0.009

† SED & F pr. values for 1988 apply to first and second rest periods only.

Table 4.10 shows expected trends, with the perennial ryegrass yields and percentage contribution to yield becoming smaller and the white clover yields and percentage contribution to yield increasing with later cuts.

4.4 DISCUSSION

When interpreting the relative yields from the three conservation cuts, the cumulative yield of the three cuts should not be calculated in an attempt to estimate the annual conservation yield from the swards. With both the later cuts, the previous continuous stocking management had a profound effect on sward tiller density, the white clover contribution, white clover stolon growth and growth habit to create a sward which was in no way comparable to that created under a three cut conservation system. The total and component yields from these swards could only be taken to represent the particular management system to which it had been subjected.

With regard to the methodology adopted to determine the percentage contribution, in terms of dry matter, of the respective sward components to the total herbage dry matter, it must be said that it is not the method generally adopted. An alternative system, often adopted, was to conduct a rapid botanical analysis to determine the proportion of the respective sward components in the total herbage fresh weight. Separate samples would be taken of each of the component species for dry matter determinations. These separate sets of data would then be used to calculate the respective contributions of the sward components to the total dry matter yield. This system is basically flawed as it is inevitable that some desiccation of the sward components takes place during both the botanical analysis and also during separations of component species for dry matter determinations. Another deficiency in this system is that grass and clover, have different initial dry matter concentrations and differential drying rates (both during the analysis and perhaps during storage). This methodology was therefore rejected.

Johnson *et al.* (1982) explored the possibility of estimating the grass / legume ratio in a sample on the basis of neutral detergent acid fibre (NDF) percentages of the herbage from a knowledge of the separate components. However, although approximate levels could be estimated, they could not accurately assess legume and grass proportions in a mixed sward.

Let us now consider the results presented in this section. The effect of the timing of the rest period on total dry matter and on grass yields was predictable with earlier cuts yielding significantly higher than later cuts and earlier perennial ryegrass / white clover associations yielding the highest at the early cut.

The contribution of white clover to yield was perhaps less predictable. It was noted that during the first harvest year, white clover percentages increased with lateness of perennial ryegrass maturity within the associations whereas during the second harvest year, earlier perennial ryegrass / white clover associations had greater white clover percentages than the later perennial ryegrass / white clover associations. A possible explanation for these conflicting trends is that during the first harvest year, the adverse effect on white clover of competition from perennial ryegrass had only had its effect on the earliest associations thus restricting clover levels. By the second harvest year, the full effects of competition had been felt by all associations. Competition from later perennial ryegrass varieties at a time when white clover development should have been at its peak may well have been responsible for lower white clover percentages with later associations.

White clover leaf size results were also revealing. The most interesting observation, with regard to white clover leaf size, was the contribution to conservation cuts of the small leaved white clover. Associations including this clover gave, somewhat unexpectedly, the highest first cut conservation yields both in terms of total dry matter and white clover dry matter. This trend was also observed for later cuts where the white clover contribution provided a large proportion of the total dry matter yield. These results appear to be contrary to the findings of Widdup and Turner (1983) and Frame and Boyd (1987) who found small leaved white clovers in association with perennial ryegrass to be less productive than perennial ryegrass associations with larger leaved white clover types. However, none of these workers were using continuous sheep grazing as the main management treatment. In this case, the sheep grazing treatment no doubt encouraged the development of a highly branched stolon mat (Davies, 1970, Munro *et al.*, 1975, Baines *et al.*, 1983 and Frame and Newbould, 1986) which when rested was capable of a rapid response in terms of growth point and trifoliate leaf production. The higher yield from the small leaved white clover / perennial ryegrass association in the first cut of the first treatment year could be attributed to the white clover adapting to a sheep grazing during the establishment year. Under a cutting only regime, the production from the small leaved white clover / perennial ryegrass association may not have performed so well. This then raises the issue, that where a sward is to be used for only one cut of silage per year, the use of a small leaved white clover variety, along with a period of conditioning prior to resting using sheep grazing, may result in higher yields. It may be pertinent however, that the small leaved white clover variety chosen was superior to other small leaved varieties available.

It was also noted that for both harvest years, the very large leaved white clover associations performed better in terms of total dry matter yield (medium size leaved white clover associations contained slightly higher white clover yields) than medium or large leaved white clover associations at first cut, whereas the medium and large leaved white clover associations performed better at second and third cuts. This could be attributed to competitive advantage due to longer petioles and larger leaves of the very large leaved clovers being greatest at first cut where the grass height is greater. While this suggests that very large leaved white clovers are appropriate for April to late May conservation rests, the adverse effect of this treatment on the persistence of very large leaved white clover in the sward, as highlighted in chapter 2 and also reflected here in the greatly reduced contribution of very large leaved white clovers to first cut yield in the second harvest year, would rule out any argument for the inclusion of very large leaved white clovers for early cut / continuous sheep grazing management.

These findings suggest that for dual purpose (cutting and grazing) management, particularly but not exclusively, where continuous stocking by sheep is involved, small leaved white clovers are the most appropriate. However it is possible that with less severe grazing allowing higher sward surface heights, medium leaved white clovers may also be appropriate. The use of blends of small and medium leaved clovers as suggested by Frame and Newbould (1984) may well have a place in situations where continuous sheep grazing and conservation managements are both used.

The contribution of perennial ryegrass ploidy to conservation cuts was small and less predictable. White clover percentages in the tetraploid perennial ryegrass / white clover associations were consistently higher than for the diploid perennial ryegrass / white clover associations. However, the higher yield of grass (probably due to higher tiller densities) from the diploid associations, hid the fact that, white clover yields from the diploid associations were sometimes, but not significantly, higher than from tetraploid associations.

4.5 CONCLUSIONS

1. Perennial ryegrass associations with small leaved white clovers gave higher total conservation yields than associations with any of the larger leaved white clovers.

2. Differences in yield of total herbage linked to white clover leaf size were due largely to differences in the yield of white clover.

3. White clover percentages in the total herbage increased with lateness of cut and smallness of white clover leaf size.

4. Diploid perennial ryegrass / white clover associations gave slightly higher yields than tetraploid perennial ryegrass / white clover associations at first cut, although these were only significant in one year.

5. Tetraploid perennial ryegrass / white clover associations had slightly higher (not significantly) white clover percentages than the diploid perennial ryegrass / white clover associations.

6. In the first year before grazing treatments had there full effect, later maturing perennial ryegrass / white clover associations had higher white clover percentages. This trend was reversed in the second year due to the comparatively greater competition from later perennial ryegrasses.

CHAPTER 5

EXPERIMENT 2

CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES

1. HERBAGE PRODUCTION ASPECTS

CHAPTER 5

CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES

1. Herbage production aspects

EXPERIMENT 2 - INTRODUCTION

Initial work showing a straight line response of grass to nitrogen, reinforced by the comprehensive Grassland Manuring studies (Morrison *et al*, 1980), subsidised fertiliser (Reid, 1976), intervention support and lack of constraints on production has resulted in many progressive grassland managers moving away from a broad based seeds mixtures and a range of perennial agricultural grass species to perennial ryegrass based swards. These mixtures may have included some white clover, as some sort of insurance policy but which was of little value to the nitrogen balance of the sward. This was because the position of perennial ryegrass was unchallenged in terms of a combination of response to nitrogen, yield of digestible organic matter, palatability, tillering ability, response to frequent defoliation and rapid regrowth. Recent interest in less intensive, low input, sustainable and environmentally sensitive grassland management systems has led to renewed interest in low or zero fertiliser nitrogen, white clover based systems.

The results of experiment 1, along with recent work by Swift *et al.* (1990; 1992a, b & c; 1993) suggested that tetraploid perennial ryegrasses were particularly suitable as companions to white clover as they had the beneficial characteristics of perennial ryegrass while their lower tillering potential allowed room for white clover to develop at the base of the sward. This then raised the issue of the value of other agricultural grasses which did not necessarily respond to "optimum / target" nitrogen levels, and which had lower tillering potential than diploid perennial ryegrass but may therefore have afforded less competition to white clover. It was also possible that modern varieties of these grasses may be improved so as to be more relevant to modern low input systems than the varieties abandoned during the sixties. The place of modern varieties of these grasses in association with white clover for clover based, zero fertiliser nitrogen systems needed to be appraised.

5.1 EXPERIMENT 2 - Perennial grass / white clover versus management

5.2 AIMS and OBJECTIVES

An experiment was therefore set up to compare diploid and tetraploid varieties of perennial ryegrass with modern strains of other possible companion grass species for white clover in a zero fertiliser nitrogen situation and also to develop appropriate cutting and grazing strategies for these swards.

5.3 TREATMENTS

Five perennial grass / white clover associations were replicated three times under three management regimes on a three hectare grazing trial.

Table 5.1 Treatments - experiment 2

Perennial grasses used in association with Menna white clover

GRASS SPECIES	VARIETY
Perennial ryegrass	Merlinda (tetraploid)
Perennial ryegrass	Magella (diploid)
Cocksfoot	Prairial
Meadow fescue	Rossa
Timothy	Goliath

Table 5.2 Treatments - Experiment 2

MANAGEMENT STRATEGIES

CG1	continuous stocking throughout the season
CG2	continuous stocking with a seven week rest April / May
CG3	continuous stocking with a seven week rest late June / July / early August

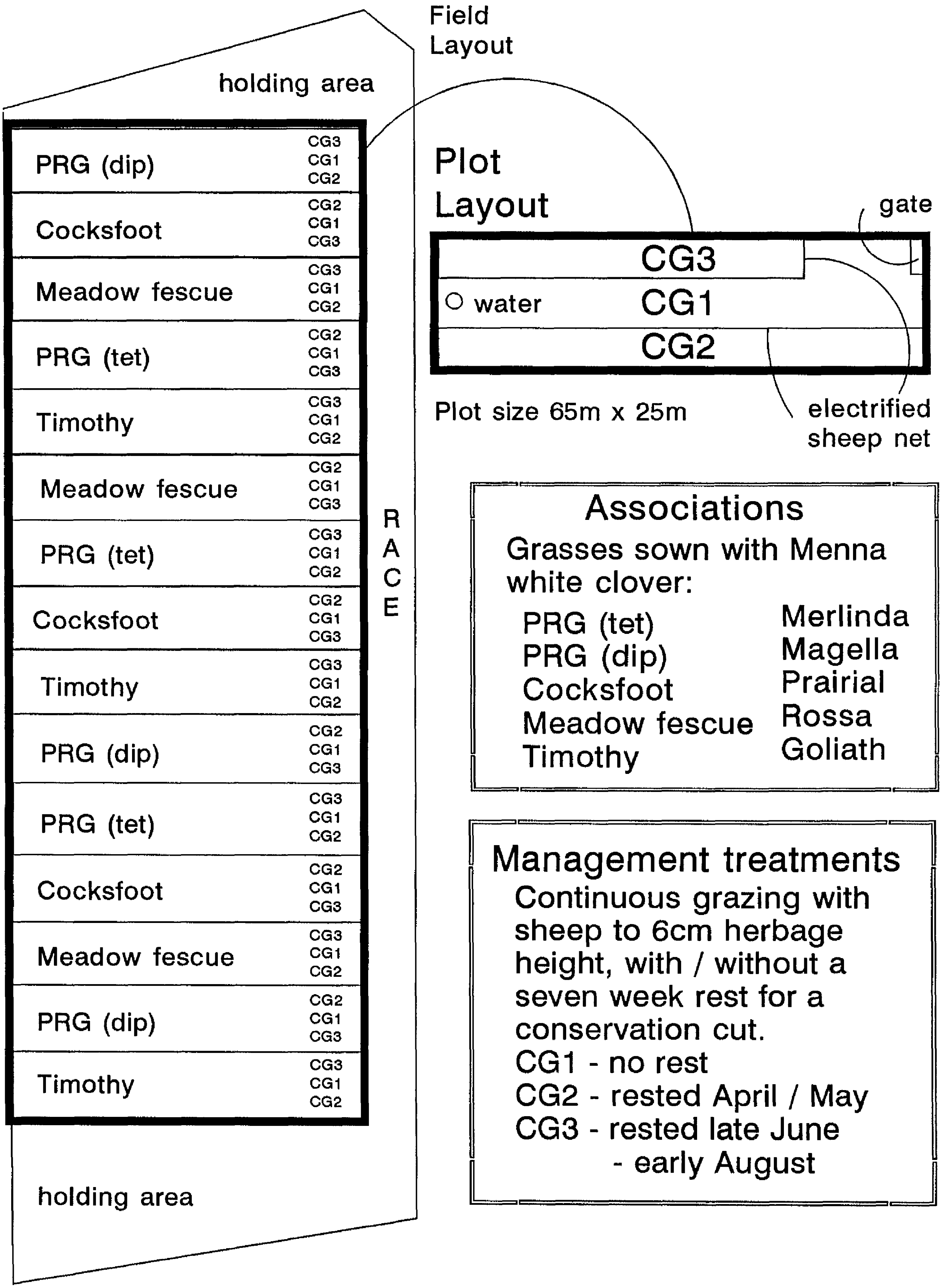
Herbage height was maintained at 60 mm using ewes with twin lambs.

5.4 EXPERIMENTAL LAY-OUT and DESIGN

Plate 5.1 Plot layout showing established plots before the imposition of cutting / grazing treatments.

Plate 5.2 Grazing management showing areas rested for a conservation cut and exclosure cages.

Figure 5.1 Experimental Layout



5.5 SITE

The field (Longholm) which was used for this experiment is one of the best on Auchincruive. The soil was alluvial gradually changing from sandy clay loam at the river end of the field to sandy loam at the other. The field was part of the Auchincruive rotation and was two years into a five year perennial ryegrass sward when it was decided that it should be used for this experiment. The sward was sprayed off with paraquat in July 1989 with the intention of sowing that August. Unfortunately, inclement weather and other priorities on the farm meant that ploughing was not completed till late September so that sowing had to be delayed till the following spring.

This however, allowed fencing to take place over the winter. (The cost of this fencing was minimised by using the project for fencing instruction for students.)

5.6 SOWING and ESTABLISHMENT

In the spring plots were harrowed with mounted harrows until in order and then rolled with a Cambridge roller. A seedbed dressing of 90 kg P_2O_5 and 90 kg K_2O was applied as "Potassic Supers". No nitrogen was applied to the seedbed. The appropriate grass seed and clover seed were mixed thoroughly and the "Nordsten" seed drill calibrated to sow the resultant seed mixture at chosen rates. These were:

Table 5.3 - Seed rates used in experiment 2.

Grass Species & Ploidy	Grass Variety	Grass seed rate (kg / ha)	Menna Clover seed rate (kg / ha)	Total (kg / ha)
Perennial ryegrass (T)	Merlinda	26	4	30
Perennial ryegrass (D)	Magella	21	4	25
Meadow fescue	Rossa	26	4	30
Cocksfoot	Prairial	21	4	25
Timothy	Goliath	14	4	18

The seeds were sown using the "Nordsten" seed drill. The seed delivery spouts were withdrawn so that the seed was broadcast, while the coulters were lowered so as to disturb the soil thus giving some of the seeds a very thin covering of soil. The plots were then given a further pass with a "Cambridge" roller to further consolidate the soil whilst at the same time aiding the shallow covering of the seeds. Seeds still in the drill after the plots were sown were used to sow blocks within the holding areas (plates 5.3)

Water provision was made in all plots using individual automatic drinking bowls. These were located in the area of the plot which would not be rested, yet were accessible when the other treatments were being grazed.

Weather for grass establishment was favourable so that the swards were ready for light grazing at about ten weeks. Unfortunately the favourable conditions for grass establishment also favoured the germination and establishment of a dense stand (300 -600 mm in height) of the annual weed *Chenopodium album* (fat hen). The plots were each given a light grazing with sheep in order to remove grass leaf, stimulate tillering of grass and to allow at least some grazing of the weed. The remaining weeds were then cut with an "Agria", raked and the waste removed. Whilst this was very labour intensive, the plots were too wet / soft and the sown species to delicate to stand any tractor traffic at this stage and any overall spray treatment was considered too risky in terms of possible physical and chemical damage. The few dock plants that had developed were spot treated with mecoprop using a knap-sack sprayer.

The plots were given a few strategic light grazings by sheep throughout the remainder of the summer and throughout the winter. The plots fitted in well to the farm system for holding, flushing and tupping small groups of ewes.

5.7 GRAZING MANAGEMENT - GENERAL

The grazing treatments were applied from the beginning of April through to the end of October. Initially sheep were allocated to each plot at four ewes and with twin lambs per plot. Sward heights were taken twice a week, Tuesdays and Fridays, using the HFRO sward stick. Twenty five readings were taken per plot. Sward heights were maintained at 60 mm by removing or adding ewes with lambs from or to plots. Surplus ewes and lambs were held in the holding areas.

The surplus ewes and lambs were given free access to blocks of diploid perennial ryegrass, meadow fescue, cocksfoot and timothy within the holding area near the river,. It was worthy of note that the timothy block was grazed down to about 20 mm whereas the other species were allowed to become so long that mob grazing with another group of sheep was necessary to keep the swards within the holding area in a good state (plate 4.3). This pointed to the superior palatability of timothy although the younger physiological age of the timothy in terms of maturity may have been partially responsible.

Plate 5.3 - "Put and take" ewes with lambs were given free access to four grass / white clover swards in the holding area. The grasses were from left to right - timothy, cocksfoot, meadow fescue and diploid perennial ryegrass. Note the relative severity of grazing .

5.8 PROCEDURES & ASSESSMENTS - REST / CONSERVATION CUT

The areas to be rested were shut off using mains powered, electrified sheep netting linked to the wire running down the edge of the plots. The area shut off during April to late May was 8 metres wide, situated away from the gate and ran the full length of the plot. Whereas the area rested Late June to early August was 8 metres wide, situated the same side as the gate, but did not run the full length of the plot. This allowed access to the gate for put and take animals, in the grazing area.

On the day of the conservation cuts, all the sheep were removed from the field and the opportunity was taken by the farm staff to carry out routine treatments on the sheep, such as dosing, dipping or shearing. The electrified netting was dismantled and removed from the plot. (In the case of the early cut, the netting would have to be re-erected in four weeks time whereas with the later cut , it was removed for the rest of the year.)

5.8.1 CUTTING - first harvest year

During the first harvest year, a standard silage "MF 70" rotary drum mower with the cutting height set at 60 mm, was used so that the cut grass was left in swathes.

* A large sample (enough to fill a 40 cm X 75 cm polythene bag) of cut herbage for dry matter content determination and chemical analysis was taken, using random grab samples, immediately the crop was cut, labelled and bagged. These samples were taken as quickly as possible to the Analytical Chemistry Department for processing.
* A smaller sample (enough to fill a 8 cm x 30 cm polythene bag) was filled using random grabs. These samples were put in the cold store for botanical analysis.
* Three ten metre lengths of swathe were then marked off, the herbage raked into piles, the piles lifted onto nets and weighed using a tared balance and tripod.
* The fresh weights, dry matter percentage and botanical analysis results were used in due course to calculate the total and relative yields in terms of dry matter of the sward components.

Plate 5.4 1990 - Conservation cuts were made using a standard mower.

Plate 5.5 3 x 10 m swathes were collected and weighed for fresh weights. Samples were taken for chemical and botanical analysis.

5.8.2 CUTTING - Second harvest year

The second harvest year, a self propelled "Haldrup 1500" machine was used, rather than a conventional mower. This machine, which was developed to cope with the proliferation and standardisation of varietal National List trials during the seventies and eighties, was chosen because of its good manoeuvrability and "on board" weighing facility.

After three machine widths had been cut off either end of the conservation plot, a full length of the plot was cut to 60 mm and weighed. This had several advantages:

* less sampling error;
* the machine was fitted with a weighing cell;
* no raking, or netting involved;
* no balance and tripod needed;
* a larger sample area could easily be taken;
* the grass can easily be dumped where it is easily disposed of.

Samples were once again taken for dry matter determination, chemical and botanical analysis.

5.8.3 PLATES

Plate 5.6 1991 Conservation cuts using "Haldrup 1500" fitted with weighing facility.

Plate 5.7 Sward surface height measurements recorded twice a week.

Plate 5.8 Merlinda perennial ryegrass / Menna white clover sward - first cut.

Plate 5.9 Merlinda perennial ryegrass (T) / Menna white clover sward - second cut.

Plate 5.10 Magella perennial ryegrass / Menna white clover sward - first cut.

Plate 5.11 Magella perennial ryegrass / Menna white clover sward - second cut.

Plate 5.12 Rossa meadow fescue / Menna white clover sward - first cut.

Plate 5.13 Rossa meadow fescue / Menna white clover sward - second cut.

Plate 5.14 Prairial cocksfoot / Menna white clover sward - first cut.

Plate 5.15 Prairial cocksfoot / Menna white clover sward - second cut.

Plate 5.16 Goliath timothy / Menna white clover sward - first cut.

Plate 5.17 Goliath timothy / Menna white clover sward - second cut.

5.9 RESULTS

Total yields (table 5.4) of herbage dry matter clearly show that tetraploid perennial ryegrass / white clover associations out-yielded diploid perennial ryegrass at both early and late cuts in both harvest years. With regard to the comparison between perennial ryegrass / white clover associations and other perennial grass / white clover associations, both the timothy / white clover association and the cocksfoot / white clover association gave higher yields at the later cut. While the meadow fescue / white clover association yielded less at both cutting dates than tetraploid perennial ryegrass it gave yields similar to those of diploid perennial ryegrass.

Table 5.5 gives full details of the April to late May and late June to early August, "D-values", for the respective perennial grass / white clover associations for both harvest years. Table 5.6 presents the total dry matter yield data together with the respective "D-value" data as yield of digestible organic matter. Tables 5.7 and 5.8 however, show that the consistently higher yields of the tetraploid associations were due, at first cut, to its greatly superior grass yield, whereas at the later cut, the advantage was due to the higher white clover yields in the tetraploid association. This was further confirmed by white clover percentages as demonstrated (table 5.9) where very low white clover percentages in the tetraploid associations at first cut are offset by correspondingly high clover percentages at the later cut. Crude protein levels (table 5.10) however were consistently higher for the diploid associations did not follow the white clover percentages. Soluble carbohydrate values (table 5.11) followed the digestibility of herbage at first cut and complemented crude protein levels at the later cut.

It was worthy of note that in the cases of the perennial ryegrass and meadow fescue / white clover associations, there was a drop in total herbage production between that of the April to late May cut and that of the late June to early August cut, of 40% - 45%. With the cocksfoot / white clover association the drop was in the order of only 14% and with the timothy / white clover association, 18%. The timothy / white clover association had comparatively higher white clover dry weights and white clover percentage at first cut, when timothy grass yields were relatively low. At second cut, when grass and total dry matter yields were high the white clover levels in the timothy / white clover association were second only to the tetraploid perennial ryegrass association in the first year and third after tetraploid perennial ryegrass and meadow fescue / white clover associations in the second year.

Table 5.4 - Effect of grass type and timing of rest period (cutting date) on herbage dry matter yield (kg/ha) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	6542	3758	0.006	448.9 (418.2)	4254	2499	0.069	359.6 (335.5)
Perennial ryegrass (D)	5172	3321			3288	1794		
Meadow fescue	5585	3048			3816	1870		
Cocksfoot	4560	3869			3645	3189		
Timothy	4507	4220			3782	2617		
Grass	F pr. 0.035	F pr. 0.056			F pr. 0.327	F pr. 0.004		
	SED 563.0	SED 341.3			SED 420.7	SED 267.8		
Mean	5273	3643	<0.001	337.7	3757	2394	<0.001	150.0

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	5150	4247	4317	4214	4363	0.109	337.7
1991	3376	2541	2843	3417	3200	0.05	270.2

() SED values in brackets are for the same levels of grass.

Table 5.5 - Effect of grass type and timing of rest period (cutting date) on herbage "D-value" of conservation cut.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	76.00	67.00	0.073	1.344 (1.231)	77.3	65.3	0.004	1.421 (1.082)
Perennial ryegrass (D)	78.33	69.73			80.50	66.73		
Meadow fescue	74.33	69.47			74.20	67.5		
Cocksfoot	69.67	65.33			70.67	61.33		
Timothy	76.00	69.87			75.93	68.57		
Grass	F pr. <0.001	F pr. 0.081			F pr. <0.001	F pr. 0.013		
	SED 0.907	SED 1.623			SED 1.346	SED 1.580		
Mean	74.87	68.28	<0.001	0.551	75.72	65.89	<0.001	0.484

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	71.30	73.62	70.85	66.00	72.25	0.002	1.025
1991	71.50	74.03	71.90	67.50	72.93	0.002	1.97

() SED values in brackets are for the same levels of grass.

Table 5.6 - Effect of grass type and timing of rest period (cutting date) on herbage Digestible Organic Matter yield (kg/ha) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	4966	2521	0.004	327.0 (310.1)	3289	1632	0.060	237.5 (238.5)
Perennial ryegrass (D)	4046	2298			2646	1195		
Meadow fescue	4137	2124			2830	1261		
Cocksfoot	3160	2526			2571	1952		
Timothy	3436	2946			2863	1795		
Grass	F pr. 0.018	F pr. 0.062			F pr. 0.18	F pr. 0.007		
	SED 414.2	SED 2.331			SED 276	SED 165.5		
Mean	3949	2483	<0.001	138.7	2840	1567	<0.001	106.7

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	3744	3172	3131	2843	3191	0.057	242.5
1991	2461	1921	2045	2262	2329	0.066	167.2

() SED values in brackets are for the same levels of grass.

workload and the experimental error inherent in the system.

The above criticisms however indicate that any system using exclosure cages is basically flawed, although in the absence of any cheap alternatives, this technique is still often adopted as the best available option and is appropriate to some comparisons e.g. growth in different geographical regions.

Table 6.2 - The effect of sown grass species (ploidy) in grass / white clover associations on herbage production and utilisation under stocking.

Livestock unit grazing days data.

Grazing year	Production parameter	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
		tetraploid	diploid					
1990	LSU grazing days	564	556	526	514	500	13.96	0.008
1991	LSU grazing days	569	586	553	558	495	16.92	0.006

Table 5.7 - Effect of grass type and timing of rest period (cutting date) on Grass dry matter (kg/ha) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	6479	2061	0.083	664.3 (849.0)	3501	1025	0.013	470.1 (460.2)
Perennial ryegrass (D)	4614	2098			2547	1065		
Meadow fescue	4995	1836			2221	738		
Cocksfoot	3840	2462			2465	2841		
Timothy	3530	2702			2320	1760		
Grass	F pr. 0.008	F pr. 0.675			F pr. 0.306	F pr. <0.001		
	SED 599.1	SED 632.7			SED 605.5	SED 294.2		
Mean	4692	2232	<0.001	379.7	2611	1486	<0.001	205.8

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	4270	3356	3416	3151	3116	0.02	284.5
1991	2263	1806	1480	2653	2040	0.064	339.3

() SED values in brackets are for the same level of grass.

Table 5.8 - Effect of grass type and timing of rest period (cutting date) on Clover dry weight (kg/ha) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	63	1697	0.601	539.6 (536.1)	565	1468	0.018	218.5 (269.6)
Perennial ryegrass (D)	558	1223			664	718		
Meadow fescue	589	1213			1429	1114		
Cocksfoot	720	1407			981	338		
Timothy	976	1517			1234	845		
Grass	F pr. 0.04	F pr. 0.929			F pr. 0.075	F pr. 0.001		
	SED 229.6	SED 641.3			SED 289.1	SED 164.9		
Mean	581	1411	0.006	239.8	975	897	0.533	120.6

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	880	891	901	1064	1247	0.842	384.1
1991	1017	691	1271	660	1040	0.002	106.7

() SED values in brackets are for the same level of grass.

Table 5.9 - Effect of grass type and timing of rest period (cutting date) on clover content in conservation cuts. Percentage clover dry matter in total dry matter.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest		April/May	Late June-early August	Grass.rest	
			F pr.	SED			F pr.	SED
Perennial ryegrass (T)	1.0	49.3			13.2	58.1		
Perennial ryegrass (D)	10.8	39.9		15.35	20.2	43.1		8.24
Meadow fescue	11.1	39.9	0.787	(17.78)	38.3	59.2	0.008	(9.51)
Cocksfoot	16.3	38.9			26.9	10.9		
Timothy	21.8	39.6			35.4	32.3		
Grass	F pr. 0.051	F pr. 0.958			F pr. 0.127	F pr. 0.001		
	SED 5.59	SED 15.93			SED 9.34	SED 7.63		
mean	12.2	41.5	0.004	7.95	26.8	40.7	0.008	4.25

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	25.1	25.3	25.5	27.6	30.7	0.96	8.8
1991	35.7	31.6	48.8	18.9	33.8	0.003	4.77

() SED values in brackets are for the same levels of grass.

Table 5.10 - Effect of grass type and timing of rest period (cutting date) on herbage Crude Protein (g/kg in Dry Matter) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED	April/May	Late June-early August	Grass.rest F pr.	Grass.rest SED
Perennial ryegrass (T)	82.0	178.3			121.0	185.7		
Perennial ryegrass (D)	103.3	191.7		15.44	138.3	192.3		16.65
Meadow fescue	116.3	213.0	0.029	(14.76)	166.3	223.7	0.063	(19.74)
Cocksfoot	127.7	172.7			155.0	158.0		
Timothy	139.7	172.7			173.3	161.3		
Grass	F pr. 0.004	F pr. 0.286			F pr. 0.022	F pr. 0.003		
	SED 10.38	SED 19.69			SED 13.06	SED 11.83		
Mean	113.8	185.7	0.029	15.44	150.8	184.2	0.004	8.83

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	130.2	147.5	164.7	150.2	156.2	0.124	11.38
1991	153.3	165.3	195.0	156.5	167.3	0.012	9.073

() SED values in brackets are for the same levels of grass.

Table 5.11 - Effect of grass type and timing of rest period (cutting date) on herbage Soluble Carbohydrate (g/kg in Dry Matter) in conservation cuts.

White clover companion grass type	Time of rest period / cut							
	1990				1991			
	April/May	Late June-early August	Grass.rest		April/May	Late June-early August	Grass.rest	
			F pr.	SED			F pr.	SED
Perennial ryegrass (T)	175.3	40.0			136.0	57.0		
Perennial ryegrass (D)	186.0	40.3		12.14	142.7	47.0		9.35
Meadow fescue	115.0	36.3	<0.001	(10.6)	80.7	41.3	<0.001	(12.44)
Cocksfoot	68.7	31.0			55.7	36.6		
Timothy	83.3	60.0			65.3	92.7		
Grass	F pr. <0.001	F pr. 0.074			F pr. <0.001	F pr. <0.001		
	SED 15.23	SED 6.65			SED 4.44	SED 5.97		
Mean	125.7	41.5	<0.001	4.74	96.1	54.9	<0.001	5.56

	Perennial ryegrass (T)	Perennial ryegrass (D)	Meadow fescue	Cocksfoot	Timothy	F pr.	SED
1990	107.7	113.2	75.7	49.8	71.7	<0.001	3.17
1991	96.5	94.8	61.0	46.0	79.0	<0.001	9.56

() SED values in brackets are for the same levels of grass.

5.10 DISCUSSION

In this experiment, the tetraploid perennial ryegrass / white clover association clearly out yielded the diploid perennial ryegrass / white clover association. While in no way seeking to detract from the tetraploid, it must be recognised that Merlinda (T) perennial ryegrass matures slightly earlier than Magella with relative ear emergence value of 34 and 45 respectively, which could partly explain the higher tetraploid yield at first cut. This would not account for the superiority of the tetraploid in terms of dry matter yield at the later cut. It is also worthy of note when the respective "D-values" of the ryegrasses are taken into account, the diploid perennial ryegrass was consistently more digestible than the tetraploid. This again can at be at least partly explain for the first cut yields by the different maturity / relative ear emergence values. Allowing a fall of digestibility of 0.5 units of "D-value" per day, the difference of 2.3 units of "D-value" in 1990 and 3.2 units of "D-value" in 1991 adequately accounts for the superiority of the diploid at first cut. This however, does not explain the superior "D-value" of the diploid at the later cuts. However, the higher "D- values" of the diploid for both cuts over the two years partly compensated for its lower yield - of digestible organic matter. It may be deduced that the consistently higher yields of the tetraploid associations were due, at first cut, to its greatly superior grass yield, whereas at the later cut, the advantage was due to the higher white clover yields in the tetraploid association. This further confirmed by the respective white clover percentage data, with very low white clover percentages in the tetraploid associations at first cut being offset by correspondingly high clover percentages at the later cut. Crude protein levels, however, were consistently higher for the diploid associations, and did not follow the white clover percentages. Soluble carbohydrate values followed the digestibility of herbage at first cut and complemented crude protein levels at the later cut. Perennial ryegrass / white clover, meadow fescue / white clover and timothy / white clover associations, crude protein levels at the late May cut reflected the lower white clover yields and more particularly the low white clover dry matter figures presented as a percentages of the total dry matter yield. This explains similar the findings of Bax and Niessan (1992).

With regard to the comparison between perennial ryegrass / white clover associations and other perennial grass / white clover associations, the ranking in terms of first cut total dry matter yields of the grass / white clover associations is, by companion grass, perennial ryegrass (T) - highest, followed in order by, meadow fescue, diploid perennial ryegrass, cocksfoot and timothy for the first year. Once the grazing treatments had had their full effect, second harvest year results for first cut showed that the comparative yield of timothy association had increased whereas the corresponding yields of diploid perennial ryegrass and cocksfoot associations had fallen, to give the white clover association ranking by companion grass of perennial ryegrass (T) - highest, followed in order by meadow fescue, timothy, cocksfoot and diploid perennial ryegrass. The elevated positions of the timothy / white clover association at the later cuts can be attributed at least partly to the white clover contribution to the dry matter and to the nitrogen balance of the sward. In contrast, Aldrich (1972) measuring grass only yields given nitrogen fertiliser showed timothy to be poorest yielder at this stage, which confirmed the findings of earlier work by Hunt (1957; 1959) and Langer (1959) who found the major part of the annual production from timothy occurred prior to ear emergence. It may also relevant that the variety of timothy (Goliath) used in experiment 2 is an improved variety which recovers more quickly from cutting or grazing than the older varieties used by these researchers.

First cut rankings for grass dry matter yields mimic those of total herbage dry matter yield for the first harvest year. However by the second harvest year the ranking has changed with diploid perennial ryegrass and cocksfoot / white clover associations out yielding meadow fescue and timothy / white clover associations in terms of grass dry matter yield. With regard to second cuts, the total herbage dry matter yields show a ranking from highest to lowest of timothy, cocksfoot, perennial ryegrass (T), diploid perennial ryegrass,meadow fescue. By the second year, the cocksfoot association had replaced timothy on the top spot, which might partly be explained by the lower rainfall prior to the second cut in 1991. This may also be one of the reasons why the diploid perennial ryegrass fell to lowest. The relatively low yield of meadow fescue was explained by the early growth pattern of this grass..

It is of particular interest that tetraploid perennial ryegrass association consistently had the lower white clover yields at first cut compared with all the other perennial grass associations while the opposite was the case at second cut, with tetraploid perennial ryegrass association having the highest white clover yields. With respect to "D-value" for total herbage, the first cut rankings for both years showed the diploid perennial ryegrass to be highest, followed in order by - perennial ryegrass (T), timothy, meadow fescue, cocksfoot. At second cut however, the timothy / white clover association had the highest "D-value" with the cocksfoot association retaining bottom spot.

In established swards, both timothy / white clover and cocksfoot / white clover swards performed well in terms of yield of digestible organic matter in a conservation cut after a late June to early August rest. The high ranking of timothy / white clover association at the later cut is attributed to the good white clover yield and the comparatively late maturity of the grass. The high ranking of the cocksfoot / white clover association at the later cut, on the other hand, was attributed to the seasonal production of the grass and its drought tolerance.

In conclusion and within the limits of the small number of species and varieties assessed, it is evident that the complementary grass : clover yield patterns of the perennial ryegrass (T) / white clover association along with its vastly superior yield of digestible organic matter indicate that tetraploid perennial ryegrass is the most appropriate companion for white clover in terms of conservation yields while managed under a mixed grazing and cutting management. Over the two years there was very little difference in terms of total herbage yield of digestible organic matter between the other companion grass association. Differences in this regard could largely be explained by weather fluctuations. The inferior "D-value" of the cocksfoot association must rule it out of any contention. It may be observed however, that an earlier diploid perennial ryegrass may to some extent have offset the apparent tetraploid advantage (Merlinda lies right on the arbitrary division between early and intermediate varieties while Magella is very close to the late varieties).

5.11 CONCLUSIONS

1. Tetraploid perennial ryegrass associations out-yielded diploid perennial ryegrass / white clover associations in both early and late conservation cuts although its first cut advantage could be at least partly attributed to perennial ryegrass varietal maturity.

2. The superior yield of the tetraploid perennial ryegrass association at first cut was due almost solely to the superior yield of grass and at second cut to the yield of white clover.

3. Crude protein levels were higher in the diploid perennial ryegrass associations than in the tetraploid perennial ryegrass association and did not appear to be directly related to the white clover content of the herbage.

4. Soluble carbohydrate levels were associated with "D-value" at first cut and complemented crude protein at second cut.

5. In established swards, both timothy / white clover and cocksfoot / white clover swards perform well in terms of yield of digestible organic matter in a conservation cut after a late June to early August rest.

6. If rested in early season, for a late May silage cut, the inflorescences of the tetraploid perennial ryegrass produced a poor quality stubble which resulted in lower herbage production under grazing later in the season.

CHAPTER 6

EXPERIMENT 2

CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES

2. Herbage production under grazing

CHAPTER 6

CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES INTRODUCTION

2. Herbage production under grazing

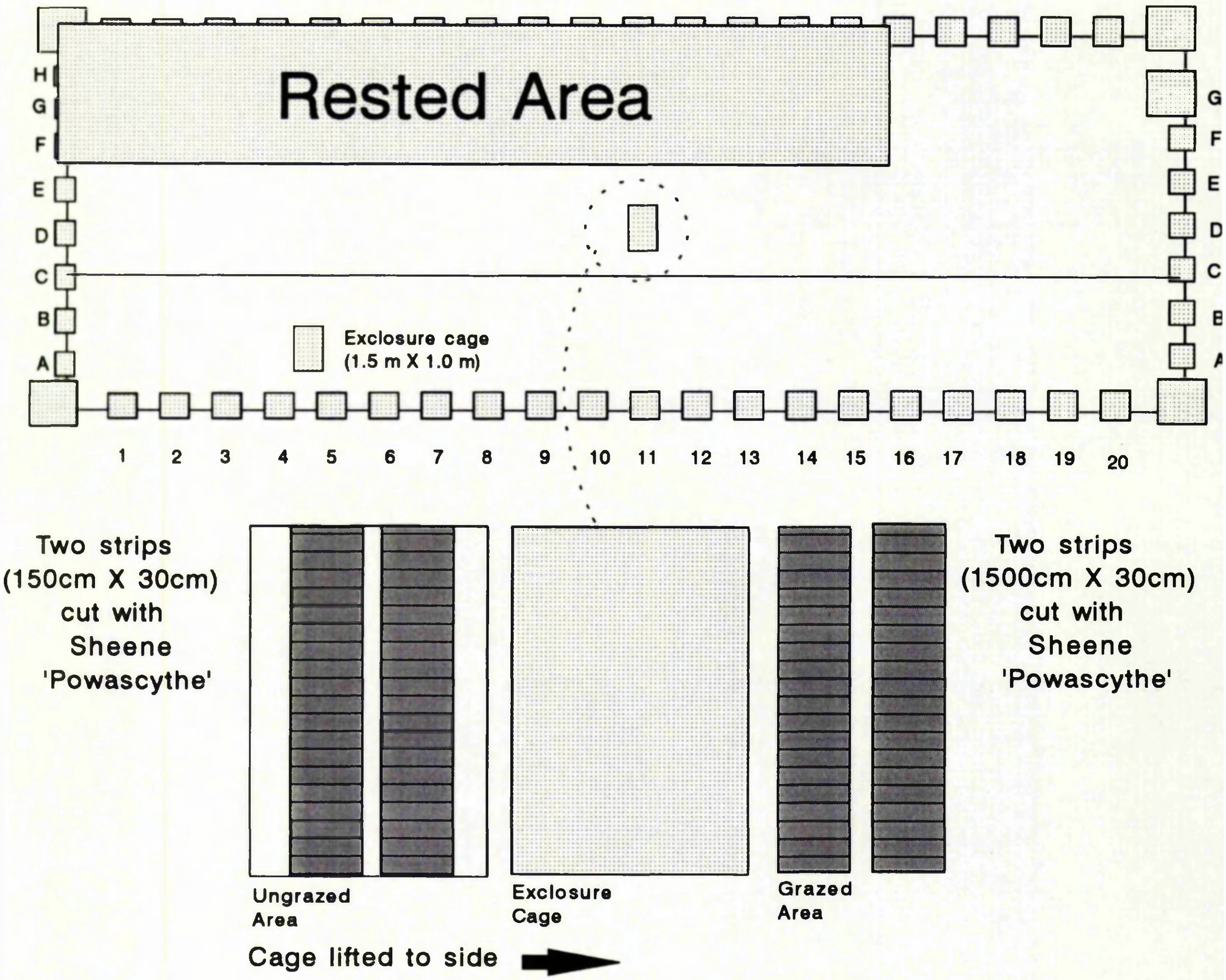
While sward production for conservation cuts was easily assessed as reported in chapter 5, the assessment of sward production and utilisation under continuous stocking is much more difficult. This is particularly the case with grass / clover swards and even more so, where comparisons have to be made between grasses with contrasting growth habits, tiller dimensions and tiller densities. Many of the results in this section are inconclusive and are included mainly as a record of work and a critique of the experimental techniques employed. Techniques have been developed to assess herbage production and utilisation under grazing directly by measuring herbage accumulation and offtake (Hodgson *et al.*, 1981) or indirectly by measuring animal intake or animal performance (Leaver *et al.*, 1982). The most commonly used method of assessing the former is to use exclosure cages. With regard to the possible direct measurement of animal intake, one alternative is to measure herbage "on offer" at various points in time and measure actual intake by n-alkane methodology (Mayes *et al.*, 1986 and Dillon and Stakelum, 1988). Le Du and Penning (1982) concluded that animal based methods of estimating intake are most reliable when herbage intake and digestibility are relatively constant. This raises doubts as to its application to rapidly changing sward conditions. Another fairly valid alternative is to assess animal performance criteria such as liveweight gain with due regard to stocking rates and initial animal condition. Neither herbage intake and animal performance techniques were used in connection with this thesis due to their high cost in terms of staff time and resources. However, records of the number of livestock unit grazing days, achieved over a period of time at a given sward height were used as a measure of sward carrying capacity.

6.1 EXPERIMENTAL METHODS AND PROCEDURES

As stated above, it was decided to use exclosure cages to assess herbage production and utilisation. Cages were set out at the beginning of each year and the protected sward and

Figure 6.1 Use of exclosure cages

The exclosure cages are positioned using pre-determined random co-ordinates based on numbered and lettered fencing stobs.



At the end of the exclosure period the cage is lifted off the protected herbage and placed adjacent to the protected area. Two 30 cm strips of herbage are then cut from the caged area and then using the cage as a marker, two 30 cm strips are cut from the grazed area on the other side of the cage. This prevents cutting the area immediately beside the protected area which may be affected by extra treading.

the grazed sward both sampled at three weekly intervals throughout the season. For comparison and validation of exclosure cage data, records were kept of sheep numbers supported by the various grass / white clover associations, which were maintained at a standard sward surface height throughout.

6.1.1 Exclosure cages

1. Single exclosure cages (1.5 m x 1 m) were placed, using random co-ordinates, on each of the treatments being grazed (no cages were put in rested treatments).
2. After a three week grazing period, two strips (150 cm x 30 cm) were cut from under the cage and two strips (150 cm x 30 cm) were cut adjacent to the cage, using a "Sheen Powascythe" modified with a 30 cm cutter bar.
3. The cut herbage from under the cage and from adjacent to the cage was bagged separately and taken to the laboratory. The cages were then re-sited within the same treatments using new random co-ordinates.
4. In the "grass" laboratory, the cut herbage samples were weighed with the weights being recorded automatically on tape. The samples were split, one sample taken for dry matter determination, and one for botanical analysis. Any surplus herbage was discarded.
5. From the fresh weights, dry matter determinations and botanical analysis caged and grazed swards can be characterised in terms of dry weight of component species per unit area.
6. The difference between the grazed and caged swards at any one cutting date can be taken to represent the quantities of the respective sward components grazed during the previous three week period.
7. The difference between the caged swards at any cutting date and the grazed sward three weeks earlier indicates the growth of sward components during that period.

6.1.2 Livestock unit grazing days

The alternative to using exclosure cages would have been to assess animal intake or liveweight gain. These methods were not possible within the resources available for this project. It was decided therefore that the best available method to assess sward carrying capacity and the pattern of herbage production was to record the grazing days from each plot. Ewes with twin lambs were used on a "put and take" basis to maintain the swards at a target 60 mm sward surface height. The use of "grazing days" however, was complicated by the fact that the twin lambs were grazing progressively more herbage as they grew. The following system for the calculation of livestock unit grazing days was adopted.

Table 6.1 Livestock unit grazing days as applied to ewes with twin lambs.
(For lambs born 1 April approximately.)

Month	Livestock unit values		
	ewe	lambs	total
April	0.09	0.01 x 2	0.11
May	0.09	0.015 x 2	0.12
June	0.09	0.03 x 2	0.15
July	0.09	0.045 x 2	0.18
August	0.09	0.06 x 2	0.21
September (until speyning)	0.09	0.075 x 2	0.24
After speyning	0.09		0.09

Livestock unit grazing day data were measured on a plot basis and represented the carrying capacity the sward over all the tested management treatments.

Figure 6.2 - herbage production in grass / white clover swards under continuous stocking with sheep.

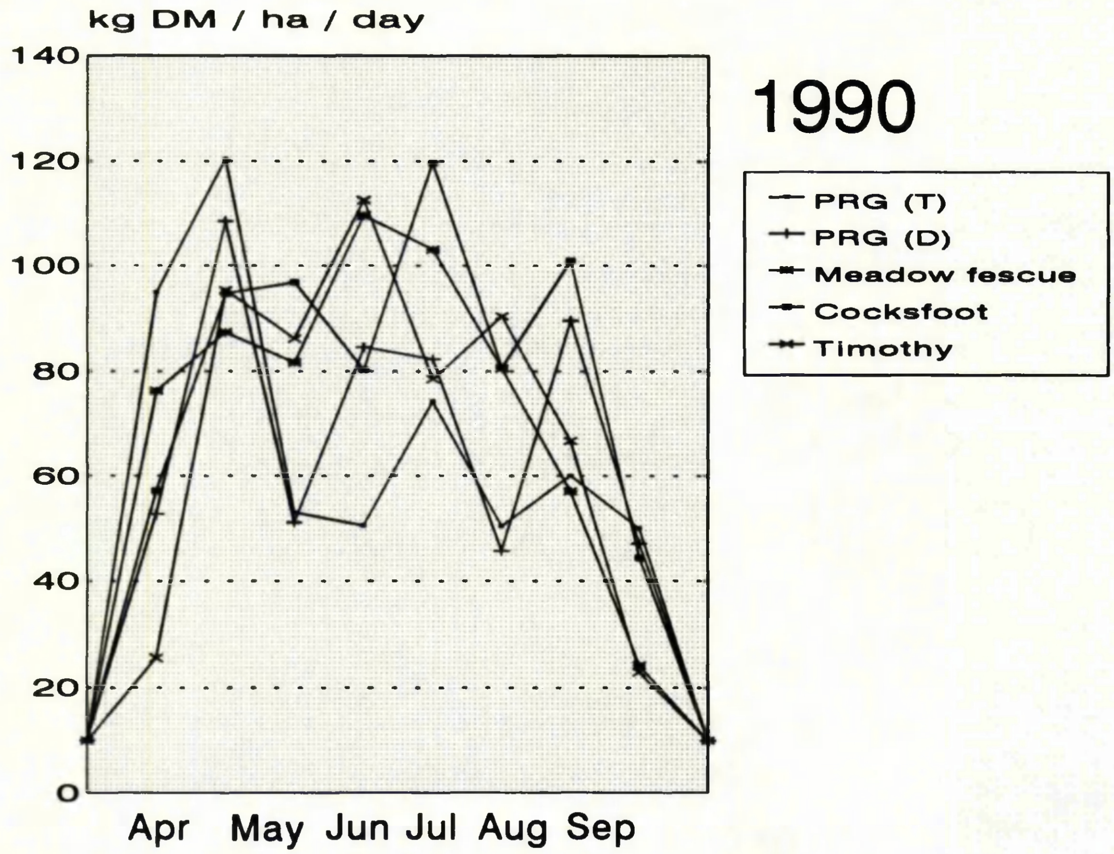
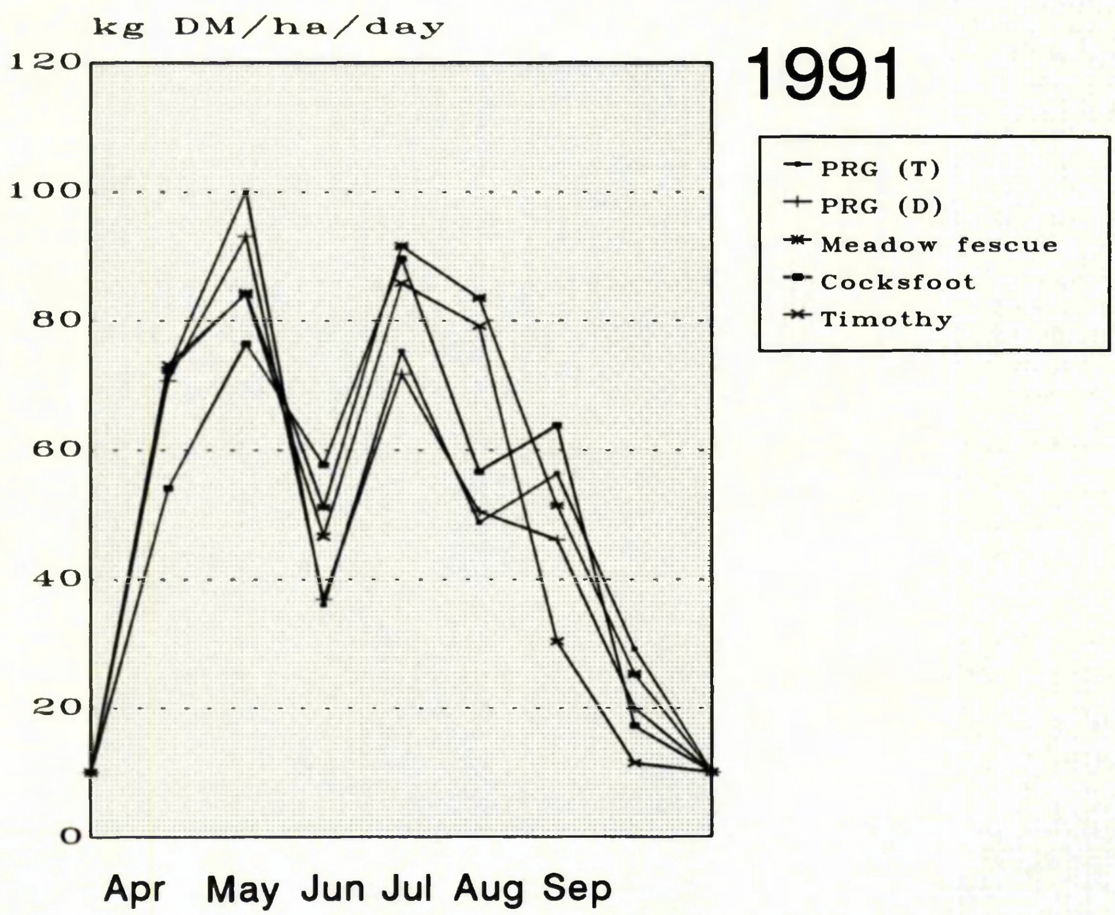


Figure 6.3 - herbage production in grass / white clover swards under continuous stocking with sheep.



6.2 RESULTS

Assessment of herbage production under continuous stocking with sheep using exclosure cages was unsatisfactory with most assessments failing to show significant differences between treatments even at the 95% level. It also has to be said that, during both years, there were occasions when botanical analysis had to be abandoned due to the deteriorating condition of the samples. Priority throughout, in such circumstances, was given to core measurements (chapter 7). The use of cumulative totals of livestock unit grazing days proved a much valuable indicator of sward carrying capacity and produced statistically significant results. The value of the exclosure cage technique as applied to this investigation must therefore be questioned and is discussed later. Tables of results for the exclosure cage data are presented in appendix 5. A few records worthy of comment and possible explanation arise from these data. Assessments of herbage production under continuous sheep stocking (tables 14.1 & 14.2) using exclosure cages showed significant differences between grass / white clover associations at the first "grazing" cuts. These values reflected the early herbage growth for both grazing years, before spring grazing had had its full effect. The earlier (3 weeks) first cutting date in 1990 gave values which largely followed the maturity classes of the respective companion grasses, with the highest yield from tetraploid perennial ryegrass followed in order by meadow fescue, diploid perennial ryegrass, cocksfoot and timothy. The 1991 values showed a similar trend, but with the exception of timothy which moved from the lowest to highest yield position. This may well have been due to the large proportion of white clover which developed in the timothy swards towards the latter part of the first grazing year coupled with the later cutting date and the responsiveness of timothy to nitrogen (clover) which is not a feature of meadow fescue which likewise had high white clover contents. This high timothy / white clover production during May, once the sward management patterns was established were confirmed with regard to daily growth rate (table 14.4) as was the clover contribution to herbage dry matter (tables 14.5 & 14.6). Also worthy of note was the fact that although the cocksfoot / white clover associations at the first "grazing" cuts were lowest in both harvest years, the highest white clover content, seen in the cocksfoot association, in the first year fell to be the second lowest in the second year. This could well have been due to the slowness of cocksfoot to establish allowing the white clover to gain an early foothold, with subsequent selective grazing with preference for white clover reducing its early competitive advantage.

The patterns of annual growth rates for the different grass / white clover associations (Appendix 5 - tables 14.3 & 14.4; figures 6.2 & 6.3) largely reflect the seasonal growth patterns for the respective grasses as influenced by the summer rainfall distribution. Cocksfoot / white clover associations in particular, maintained production at times of low rainfall.

6.3 DISCUSSION

Exclosure cages have been used in many shapes and forms for a variety of situations over a number of years (Brown, 1954 and Frame, 1981), the concept being that a cage is erected over an area of sward within a grazed area. After a growth period, the sward under the cage is cut and the herbage compared with herbage cut by the same method from an adjacent grazed area of identical size. The differences in terms of yield and botanical analysis are used to estimate production of the sward under grazing.

Different techniques have been adopted with regard to the use of exclosure cages. Frame (1981) notes one technique involving pre-trimming of the grazed area, on which the cage is to be erected, to a standard height at the beginning of each exclosure period. The herbage within the exclosure is cut again at the end of the exclosure period and is taken to represent the growth during that period. Another cut of an equivalent area is taken from the grazed sward adjacent to the exclosure as a measure of the herbage "on offer". It can be argued however that pre-trimming itself imposes a separate and more severe treatment from which the sward takes time to recover before "normal" (nevertheless, non grazed) growth recommences.

An alternative technique is not to pre-trim and to use the difference between the grazed area cut at the beginning of the exclosure period (A) and the post exclosure cut (B) to asses the quantity of herbage removed by grazing (B - A= removal). This technique relies to a greater extent on uniform grazing. This latter technique is the one adopted in this experiment.

The criticisms levelled at this technique are:

1. that as soon as stock are excluded from an area of sward, that sward ceases to be grazed and thus sward growth characteristics in terms of tillering of grass and morphology of different white clover cultivars cease to be those of a grazed sward (Brown and Evans, 1973; Frame, 1981)
2. selective grazing, particularly by sheep, no longer applies so that estimates of herbage "on offer" are biased;
3. shading effects due to longer herbage are introduced if the protected period is prolonged;
4. effects of treading are reduced (Brown and Evans,1973);
5. animal excretion effects are excluded;
6. a different micro-climate may exist within the cage (Williams, 1951, Milner and Hughes, 1968, t'Mannetje, 1978, Frame, 1981, Meijs *et al.,* 1982 and Marsh and Laidlaw, 1978) although the extent of this varies with the mesh size and the duration of the period of protection.
7. when lifting cut herbage, it is easier, to pick up the longer herbage from within the cage than the shorter herbage, which is more likely to scatter, from the grazed area;
8. the cage may influence the behaviour of animals in the vicinity of the cages leading to sward damage in that area (Meijs *et al*, 1982).

To minimise the effect of the above drawbacks the period of exclusion should be minimised thus allowing the cages to be relocated more frequently. This however does not totally remove the above shortcomings of the technique. In most cases it is probably impracticable to reduce the exclusion period to less than a week or so since it follows that the shorter the exclosure period, the more samples have to be taken, which increases the

With regard to sheep grazing, Laidlaw and Frame (1988) concluded that the clover content of grass / white clover swards is likely to be an under estimate both of clover in animal diet and the actual contribution clover is making to sward productivity because of the selective grazing of the clover.

Values for total herbage production under gazing (Appendix 5 - tables 14.1 & 14.2 and summarised 6.2) showed cocksfoot and meadow fescue associations with white clover to be highly productive in the first full grazing year while in the second grazing year, comparative yields from meadow fescue were maintained, yields from cocksfoot / white clover associations fell while those of tetraploid perennial ryegrass association yields rose.

Table 6.3 - Ranking of sward productivity under continuous sheep grazing (best - top; lowest - bottom).

1990		1991	
Exclosure cages	LSU grazing days	Exclosure cages	LSU grazing days
Cocksfoot	PRG (tetraploid)	Meadow fescue	PRG (diploid)
Meadow fescue	PRG (diploid)	PRG (tetraploid)	PRG (tetraploid)
PRG (diploid)	Meadow fescue	Cocksfoot	Cocksfoot
PRG (tetraploid)	Cocksfoot	Timothy	Meadow fescue
Timothy	Timothy	PRG (diploid)	Timothy

(N.B. Exclosure cage rankings were for continuous stocking only, whereas the grazing days rankings were for the whole paddock which included continuous stocking alone and early and late rested areas.)

The changes in the relative position of these three associations can be accounted for, in

Plate 6.18 Timothy plant basal bulbs and roots littering the sward.

the cases of tetraploid perennial ryegrass and meadow fescue by their comparative open habit which allowed white clover to develop whereas in the case of cocksfoot, early white clover advantage gave way to disadvantageous selective grazing. While white clover levels in timothy / white clover associations were high, hard grazing due to the high palatability of both sward components kept timothy / white clover production levels down.It was very noticeable, that when timothy swards were grazed by sheep, a large proportion of the timothy plants were pulled from the sward littering the sward surface with timothy "bulbs" at various stages of decay.

The ranking shown in table 6.3 contrasts grazing production from exclosure cage data for a continuously stocked sward only with livestock unit grazing days from swards given a range of managements. Table 6.4 shows the rankings for different grazing / cutting managements.

Table 6.4 Ranking of herbage production under grazing - exclosure cage data (1 - highest; 5 - lowest)

	1990			1991		
Rest treatment	none	early	late	none	early	late
Perennial ryegrass (T)	4	5	3	2	5	1
Perennial ryegrass (D)	3	1	1	5	4	4
Meadow fescue	2	4	2	1	2	2
Cocksfoot	1	2	4	3	1	3
Timothy	5	3	5	4	3	5

While the rankings in table 6.4 largely reflect the different seasonal and climatic responses of the companion grasses, there was the indication that the production of a diploid perennial ryegrass / white clover sward was enhanced by a rest from continuous stocking whereas the tetraploid perennial ryegrass production from the early rested sward was adversely affected. This in keeping with the observation that when an April to late May silage cut was taken from the tetraploid perennial ryegrass association, the grass stubble continued to grow slightly and then died, leaving a very coarse, open sward. This stubble remained, ungrazed for the remainder of the season.

Values for herbage production based on livestock unit grazing days (table 6.2) with the associated rankings (table 6.3) gave a completely different picture to that suggested by the exclosure cage data. The livestock unit grazing day data clearly places perennial ryegrass / white clover as the most productive associations and timothy as the least with cocksfoot and meadow fescue occupying third and fourth positions. Some possible reasons for this discrepancy of results are as follows:

1. The comparatively high tillering capacity of both perennial ryegrasses resulted in a greater proportion of growth taking place below the "Sheen" cutting height so that was not sampled and therefore not accounted for.
2. Sheep grazing on the other hand penetrated deeper into the canopy with the greatest herbage bulk being grazed nearest the ground.
3. The meadow fescue production appeared to be high under the exclosure cages.This resulted from the early maturity of the species giving rise to the tendency, early on, to produce flowering heads. With other species such as perennial ryegrass, these potentially flowering tillers would have been grazed so that the sward would have been maintained in a vegetative state. However, the fact that the meadow fescue sward was very open, allowed the sheep to graze the white clover and also, the leaves attached to the flowering stalk. Within the cages these flowering heads developed rapidly, as did the associated leaves, thus creating enhanced yields.
4. The initial comparatively high yields from the cocksfoot associations from the cage assessments could, to a large extent, be due to the open nature of the sward at ground level to 60 mm above ground level with most of the production being above that height. Thus production from within the cages was not a true reflection of production under grazing.
5. The white clover dry matter as a percentage of the total dry matter data /

Table 6.6 - The effect of sown grass species (ploidy) and the imposition of a rest for a conservation cut on the percentage of white clover in grass / white clover associations under continuous stocking with sheep.

Based on the white clover dry matter as a percentage of the total herbage dry matter production in cages rested from 5 September to 23 November (this allowed time for swards to adjust to a grazing habit after rests earlier in the season).

1990

Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	Grass.rest		Rest
	tetraploid	diploid				SED	F pr.	
No rest	8.49	10.28	13.87	3.86	18.29	5.318		10.96
April - late May	8.90	5.45	20.49	2.79	17.87	(4.405)	0.73	11.10
Late June - early August	5.54	8.76	19.43	4.36	21.36			11.89
Companion grass	7.64	8.16	17.93	3.67	19.17	3.917	0.015	SED 1.97 F pr. 0.879

() SED values in brackets are for the same levels of grass.

(Appendix 5 - tables 14.5 & 14.6 and summarised in table 6.5) show clearly that white clover percentages from within the cages were consistently higher than in the grazed area. This means that the white clover leaves in the grazed area often do not develop before they are grazed, so about half of the white clover dry matter accumulated within the cages was not on offer to the grazing animal. This confirms the conclusions of Laidlaw and Steen (1989) that, in continuously stocked swards, the contribution of white clover to growth was much higher than its presence suggested.

Table 6.5 - The mean values for white clover dry matter as a percentage of the total herbage dry matter for grazed and three week caged swards.

Year	White clover % in exclosure cages.	White clover % in the grazed sward
1990	32.7	9.9
1991	29.4	16.7

The above criticisms of the exclosure cage technique must raise questions as to the validity of its use in comparing herbage production between such widely divergent swards and for use in grass / white clover swards in particular. One could conclude that the effects of the above criticisms would have been less if all plots had been of the same grass species, and if exclosure periods had been shorter. In practice this was not possible due to cost. The use of motorised sheep sheers would have allowed cutting to be closer to the ground. However, soil contamination of herbage would have introduced another source of error although this could be largely corrected by the use of organic matter rather than dry matter (Frame, 1981).

The livestock unit grazing days technique adopted also has its drawbacks in that in small plots, fine tuning is difficult, as the minimum adjustment to stocking rate early in the year

Table 6.7 - The effect of sown grass species (ploidy) and the imposition of a rest for a conservation cut on the percentage of white clover in grass / white clover associations under continuous stocking with sheep.

Based on the white clover dry matter as a percentage of the total herbage dry matter in cages rested from 12 September to 21 October (this allowed time for swards to adjust to a grazing habit after rests earlier in the season).

1991

Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	Grass.rest		Rest
	tetraploid	diploid				SED	F pr.	
No rest	12.9	10.5	37.7	10.1	53.9	8.068		25.0
April - late May	3.9	6.8	34.8	16.6	49.7	(5.003)	0.002	22.4
Late June - early August	22.3	29.4	67.8	11.2	59.1			37.9
Companion grass	13.0	15.6	46.8	12.2	54.2	6.958	<0.001	SED 2.237 F pr. <0.001

() SED values in brackets are for the same levels of grass.

is, one ewe and her lambs. The livestock unit grazing day data could not be substantiated by livestock production data as liveweight gain or loss was not monitored. Likewise, while the method of adjusting stocking rates according to grass height is ideal for any particular type of sward taken in isolation, it was evident for example that a diploid perennial ryegrass sward of a given height represented a vastly different amount of herbage "on offer" to that of a meadow fescue / white clover sward of the same herbage height. More work is needed to establish equivalent herbage height data to represent herbage "on offer" each grass species, with and without white clover as most work so far has focused on perennial ryegrass swards. The effects of the grazing / cutting management on the white clover content of the swards were clearly demonstrated by the last caged cut of both grazing years (table 6.6 & 6.7). By the time these assessments were made, all the swards had had adequate time to adjust from the conservation rest and revert to a grazed growth habit. The highly significant differences for 1991 showed that in all associations, the white clover component benefited from a rest late June to early August. This was particularly the case with diploid perennial ryegrass. However in both years, the white clover content of diploid perennial ryegrass swards was shown to be severely depressed by an April to late May conservation rest.

6.4 CONCLUSIONS

1. The use of exclosure cages is not an appropriate method of quantifying herbage production under grazing for use in comparing herbage species / varieties with dissimilar growth habits.

2. The high conservation yields and complementary grass / white clover yield patterns of the tetraploid perennial ryegrass / white clover association suggest that it is an ideal sward for mixed cutting and sheep grazing managements although a later conservation cut would be preferable to late May cut.

CHAPTER 7

EXPERIMENT 2

CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES

2. SWARD ASPECTS

Passing thoughts while counting annual meadow grass tillers and white clover nodes:

I read the news today oh boy
Four thousand holes in Blackburn, Lancashire
And though the holes were rather small
They had to count them all
Now they know how many holes it takes to fill the Albert Hall.
I'd love to turn you on.

LENNON and McCARTNEY, (1967)

CHAPTER 7
CUTTING AND GRAZING SYSTEMS FOR ASSOCIATIONS OF WHITE CLOVER WITH PERENNIAL GRASSES
2. Sward aspects

In chapter 2, it was argued that due to the small plot size, non destructive techniques such as grid and point quadrat assessments were the most appropriate and were therefore adopted. These assessments gave the best possible guide to the quantity of white clover in the sward without causing physical damage which might adversely affect the treatments or future assessments. These techniques were used in an attempt to quantify the amount of white clover foliage in the sward. Such indicators of sward white clover content were extremely sensitive to small, short term fluctuations in foliage stand brought about by variations in grazing pressure, selective grazing, climate and seasonality of growth. Unfortunately they can only give a guide to sward white clover status as they cannot clearly reflect the white clover's reserves and potential for growth which are resident in both above ground and buried stolons. In experiment 1, therefore these assessments were used to compare swards after a period of uniform management, rather than to predict white clover's potential for growth. This larger experiment allowed limited destructive sampling to take place without prejudice to the validity of the treatments or future assessments. Given the opportunity for such sampling it was decided that a measurement of white clover stolon in terms of length or weight per square metre would give the best measure of sward white clover status.

7.1 METHODS and MATERIALS

7.1.1 Field procedures

Ten representative cores were taken at random using a "Golf course" type corer (100 mm) during a zig zag traverse over the treatment area. Due to the time taken and labour intensive nature of sward core investigations the number of such assessments had to be limited. It was also pertinent that under grazing the sward components are constantly in a state of change due to their respective seasonality and the associated species. This state of flux is further complicated when there are changes of management from grazing to conservation or vice versa. It was therefore decided that cores should be taken, only twice a year, at times when the sward state was relatively stable and the longer term effects of the treatments could best be evaluated. The corings took place at the beginning of April, at which time the effects of winter conditions would be most evident and at the end of October, after the relevant swards had had over two months to re-adjust to a grazing situation after the second rest period. Cores, taken at this time of year, were thought to reflect the overall and long term effects of the grazing / conservation managements.

Field procedures

Representative cores were taken at random while walking in a zig - zag manner over the sampling area. The cores are preferably about 50 mm in depth, placed in polythene bags and stored in a cold store until processing in the laboratory.

7.1.2 Laboratory procedures

Full Treatment

1. Each core was taken separately;
2. All above-ground stolons (with leaves) were removed from the surface of the core, using a sharp pair of scissors and placed or marked so that they could be identified.
3. The core was then broken apart gently and the grass tillers and remaining clover stolons with leaves, teased apart. (with heavy clay soils it is sometimes necessary to wash the soil away before this can be done). The below-ground or buried stolons were also placed or marked so that they could be identified.
4. At this stage (if not already done) both above-ground and buried stolons were washed to remove all traces of soil. Small soil sieves were ideal for this. The two clumps of stolon were then placed on paper towels to dry while grass tiller counts commenced.
5. The grass component of the sward was then teased out into individual plants

and identified and placed or marked appropriately.

6. For each grass species identified, the number of tillers were counted and recorded. If no other measurements were required from the grass component, the grass was discarded.
7. The above-ground stolons were then taken and, if required, number of nodes, and number of growth points counted and recorded (this procedure was repeated with buried stolons).
8. The leaves with petioles were then cut from the stolons, with both foliage and stolons placed or marked appropriately, while roots were cut from the stolons and discarded. With young clover plants, however, it was desirable to count the number of tap roots (this procedure was then repeated with buried stolons).
9. The above-ground stolons were then cut into straight sections and these sections placed end to end along a ruler. Once done the total length of above ground stolon was measured and recorded (this was again repeated with buried stolons).
10. Foliage from above-ground stolons, above-ground stolons, foliage from buried stolons and buried stolons were put into trays, placed in an oven overnight and dry weights of the components measured and recorded the following morning. If individual core dry weights were not required, bulked samples were used.

The above procedure was very time consuming and in order to get meaningful results from cores it was sometimes necessary to rationalise and reduce the number of parameters measured to the minimum absolutely necessary.

The procedures detailed in this section were developed using an existing perennial ryegrass / white clover swards which was part of a cutting and grazing management experiment at Crichton Royal farm. Once the procedures were established, they were adopted in this experiment.

The time consuming nature of core investigations along with teaching constraints meant that the type and number of measurements which were made were adjusted with regard to staff availability and the physical condition of the cores. It was found that during cold storage, grass tillers along with white clover leaves and growth points deteriorated fastest whereas white clover stolon survived in a good state for several weeks longer. This meant that at times of peak field activity, only white clover stolon length and weight assessments could be made. When possible the following measurements were made:

* above ground stolon length;
* above ground stolon weight;
* buried stolon length;
* buried stolon weight;
* number of white clover growth points;
* number of sown grass tillers;
* number of annual meadow grass tillers.

Cores were taken at the end of the establishment year and at the beginning of the first treatment year in both cases, before the application of any of the grazing / cutting treatments. Cores were also taken after the experiment was completed in the March and July of the third grazing year after establishment. During that year, the swards were still subjected to continuous stocking with sheep, but no rest treatments were applied.

Table 7.1 - The effect of grass species (and ploidy) on the clover stolon development
CORES - Clover stolon length (m/m^2)

	Stolon	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
		tetraploid	diploid					
Post grazing cores - November of establishment year	total	12.34	12.33	15.63	15.12	23.36	1.476	<0.001
Pre-grazing cores - March of first full grazing year	above ground	7.67	7.67	17.00	13.33	14.00	2.293	<0.001
	buried	30.7	36.0	59.7	51.0	63.0	3.99	<0.001
	total	38.3	43.3	76.3	64.7	77.0	4.57	<0.001
Post grazing cores - November of first full grazing year	above ground	3.39	3.57	9.80	4.13	13.04	1.963	0.003
	buried	53.6	52.7	90.8	58.8	90.9	7.90	0.002
	total	57.0	56.4	100.8	62.9	103.9	8.60	<0.001
Pre-grazing cores - March of second grazing year	above ground	10.39	3.57	8.83	5.77	7.78	3.704	0.508
	buried	61.1	58.0	94.8	58.8	85.0	22.02	0.426
	total	70.9	63.7	104.7	65.1	93.3	25.06	0.502
Post grazing cores - November of second grazing year	above ground	8.4	11.3	18.2	7.2	24.7	4.719	0.027
	buried	90.2	80.6	153.3	67.4	127.3	14.82	0.002
	total	98.6	91.9	171.6	74.6	151.9	16.40	0.001
Pre- grazing cores - March of third grazing year	total	49.4	29.7	65.2	36.6	67.4	18.24	0.243
July cores of third grazing year	total	42.2	21.5	75.2	59.7	74.0	6.247	<0.001

7.2 RESULTS

Cores taken in November of the establishment year (table 7.1) showed the lowest stolon lengths were found in the perennial ryegrass plots with the highest in the timothy / white clover associations. Meadow fescue and cocksfoot were intermediate in this regard. Sown grass tiller numbers were highest in the perennial ryegrass / white clover associations and lowest in the timothy / white clover associations with cocksfoot and meadow fescue / white clover associations intermediate (table 7.2).

During the first winter, white clover stolon lengths at least tripled in all associations with a significant difference being established between the perennial ryegrass associations and the others. By this time, a significant and expected trend in sown grass tiller numbers had developed (table 7.2) with the highest values in the diploid perennial ryegrass associations, the lowest in the timothy and meadow fescue associations, with the cocksfoot and tetraploid perennial ryegrass associations being intermediate in this regard.

During the first treatment year, white clover stolon lengths in both timothy and meadow fescue associations continued to rise, as did those in both the ryegrass associations albeit to a lesser extent. Within the cocksfoot associations however, stolon lengths remained fairly static.

The second treatment year reinforced the trends observed earlier. The greatest stolon lengths were in the meadow fescue / white clover association, followed closely by those in the timothy / white clover association at 172 m/m^2 and 152 m/m^2 respectively. The white clover stolon lengths in the perennial ryegrass associations had increased over the year but were considerably lower than those in the timothy and meadow fescue associations. The tetraploid perennial ryegrass / white clover association had marginally more stolon than the diploid perennial ryegrass association with 99 m/m^2 and 92 m/m^2 respectively. The white clover stolon length in the cocksfoot white clover association rose very slightly over the year to 75 m/m^2. These white clover stolon length values showed an inverse relationship to grass tiller numbers (table 7.2). The meadow fescue and timothy / white clover associations had 4715 and 4127 tillers / m^2 respectively, cocksfoot

Table 7.2 - The effect of sown grass species (ploidy) in grass / white clover associations on grass tiller number.
CORES - Perennial (sown) grass tiller number (number/m^2)

	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
	tetraploid	diploid					
Post grazing cores - November of establishment year	1517	1398	910	1006	770	153.1	<0.001
Pre-grazing cores - March of first full grazing year	4545	6061	3145	4083	2881	252.1	<0.001
Post grazing cores - November of first full grazing year	6095	10187	3059	4701	2785	530.4	<0.001
Post grazing cores - November of second grazing year	8145	12856	4715	8439	4127	833.6	<0.001
July cores of third grazing year	8744	11989	764	5473	4773	2267	0.007

Table 7.3 - The effect of sown grass species (ploidy) in grass / white clover associations on annual meadow grass tiller number.
CORES - Annual meadow grass tiller number (number/m^2)

	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
	tetraploid	diploid					
Post grazing cores - November of first full grazing year	622	403	1212	699	1116	430.9	0.306
Post grazing cores - November of second grazing year	1082	639	1733	1587	1737	569.7	0.303
July cores of third grazing year	2876	1794	10258	4620	4862	1469	0.003

and tetraploid perennial ryegrass / white clover associations had 8439 and 8145 tillers / m^2 respectively and diploid perennial ryegrass had 12856 tillers / m^2.

During the third winter clover stolon lengths were reduced in all associations to at least half the November length and to a third of the November length in the case of the diploid perennial ryegrass. In July of the third post establishment year (during which continuous sheep stocking was continued) a core assessment was made and it was observed that white clover stolon lengths rose in all but the perennial ryegrass associations.

It was also noted that meadow fescue tiller numbers had fallen to 2627 / m^2 in the late rested treatment by the end of the second grazing year and by July of the third year to 764 tillers / m^2 compared with 4773, 5473, 8744 and 11989 in the timothy, cocksfoot, tetraploid perennial ryegrass and diploid perennial ryegrass / white clover associations, respectively. This suggests therefore that meadow fescue in association with white clover is not persistent enough to withstand continuous stocking with sheep and that the imposition of a rest for a conservation cut, whatever its timing can do little to improve the situation (table 7.5). High white clover stolon lengths in meadow fescue / white clover associations (table 7.5) appear to be unaffected by cutting / grazing management treatment.

Cores taken after the cutting / grazing management treatments had been applied for the second year (table 7.5) suggest that white clover stolon length in tetraploid perennial ryegrass swards is adversely affected by any rest for a conservation cut. This adverse effect on white clover stolon length was greatest when the sward was rested during the period from April till late May.

Table 7.4 - The effect of grass species (and ploidy) on the clover stolon development

CORES - White clover stolon weight (g Dry matter /m^2)

	Stolon	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
		tetraploid	diploid					
Post grazing cores - November of establishment year	total	10.14	11.35	9.87	10.04	19.59	1.122	<0.001
Pre-grazing cores - March of first full grazing year	above ground	3.67	5.00	6.67	6.33	7.00	1.270	0.073
	buried	16.7	25.7	47.0	27.0	35.3	4.95	<0.001
	total	20.3	30.7	53.7	33.3	42.3	5.25	<0.001
Post grazing cores - November of first full grazing year	above ground	3.74	5.23	8.91	3.13	12.86	2.625	0.028
	buried	41.2	41.3	98.6	54.3	77.6	20.97	0.098
	total	45.0	46.6	107.6	57.3	90.4	22.01	0.073
Pre-grazing cores - March of second grazing year	above ground	5.92	2.67	6.55	4.67	4.05	2.781	0.583
	buried	31.5	37.6	52.4	31.2	50.1	14.93	0.790
	total	37.3	39.1	58.4	38.9	54.2	17.18	0.850
Post grazing cores - November of second grazing year	above ground	7.1	9.4	16.8	4.7	20.8	4.328	0.027
	buried	67.3	64.1	126.1	52.3	109.9	14.81	0.004
	total	74.4	73.8	143.1	56.9	130.7	16.81	0.003
Pre- grazing cores - March of third grazing year	total	25.8	14.9	35.2	17.3	39.0	9.30	0.115
July cores of third grazing year	total	33.1	13.6	58.9	42.4	51.3	9.56	0.011

In the case of diploid perennial ryegrass, the late June to early August rest allowed white clover stolon to increase to lengths greater than in the tetraploid swards. Once again, white clover stolon lengths were significantly lower in diploid swards that were rested during April to late May. With regard to the response to rest management treatments in terms of tillering, tetraploid perennial ryegrass tiller number was increased by an early rest and reduced by the later rest, whereas with the diploid perennial ryegrass tiller number was only slightly reduced by an early rest. With both timothy and cocksfoot, any rest for a conservation cut had an adverse effect on white clover stolon length. In both cases the later rest had the most severe effect.

With regard to the number of white clover stolon growth points per unit length (table 7.6) the mid to late summer rest in the cases of both ryegrasses and meadow fescue / white clover associations, gave the highest number of white clover stolon growth points. Conversely with both timothy and cocksfoot / white clover associations, continuous stocking produced the greatest number of white clover growth points. When stolon weight per unit length was examined (table 7.7), an identical pattern was observed.

The overall effect of companion grass type on the abundance of annual meadow grass in the sward was seen (table 7.3) in a consistent trend over the three years with an inverse relationship between annual meadow grass tiller number and sown grass tiller number. Thus diploid perennial ryegrass with the greatest tiller density had in the lowest annual meadow grass infestation. Tetraploid perennial ryegrass, cocksfoot, timothy and meadow fescue had progressively lower tiller densities and correspondingly greater annual meadow grass tiller densities. By the third summer, by which time meadow fescue tiller numbers had dropped to 764 tillers / m^2 (table 7.2) the annual meadow grass density had risen to 10258 tillers / m^2 (table 7.3).

Table 7.5 - The effect of grazing / cutting management and companion grass in grass / white clover associations
CORES - November of second grazing cutting management year.

Sward parameter	Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	Grass F pr./SED	Rest F pr./SED	Grass.rest F pr./SED
		tetraploid	diploid						
Sown grass tiller number (tillers / m^2)	no rest	8556	17461	4741	8828	4550	<0.001	<0.001	<0.001
	April - late May	10878	15245	6778	8246	4333	833.6	582.6	1351.5 (1302.8)
	late June - early August	5000	5861	2627	8242	3497			
Annual meadow grass tiller number (tillers / m^2)	no rest	2131	1226	3115	2852	2559	0.308	<0.001	0.461
	April - late May	1069	598	2016	1855	2415	569.7	282.8	768.8 (632.3)
	late June - early August	47	93	68	55	238			
Above ground stolon length (m/m^2)	no rest	5.6	5.4	14.6	6.5	31.2	0.027	0.017	0.011
	April - late May	5.5	5.1	12.9	9.0	23.8	4.719	2.208	6.206 (4.937)
	late June - early August	13.9	23.3	27.0	6.1	19.2			
Buried stolon length (m/m^2)	no rest	119.5	83.7	155.1	90.5	175.5	0.002	<0.001	<0.001
	April - late May	65.4	51.0	154.8	66.3	129.1	14.82	6.68	19.19 (14.95)
	late June - early August	85.7	107.2	150.0	45.4	77.4			
Total stolon length (m/m^2)	no rest	125.1	89.0	169.7	97.0	206.3	0.001	<0.001	<0.001
	April - late May	71.0	56.1	168.0	75.3	152.7	16.40	7.19	21.00 (16.07)
	late June - early August	99.7	130.7	177.0	51.3	96.7			

Table 7.5 - (Continued)

Sward parameter	Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	Grass F pr./SED	Rest F pr./SED	Grass.rest F pr./SED
		tetraploid	diploid						
Above ground stolon weight (g/m^2)	no rest	3.3	4.0	12.0	3.7	23.3	0.027	0.002	0.025
	April - late May	4.3	3.7	11.0	5.0	22.0	4.328	2.086	5.765 (4.663)
	late June - early August	13.7	20.7	27.3	5.3	17.0			
Buried stolon weight (g/m^2)	no rest	87.0	60.0	112.3	66.3	142.3	0.004	0.025	<0.001
	April - late May	43.7	37.0	124.3	54.0	116.7	14.81	6.18	18.62 (13.83)
	late June - early August	71.3	95.3	141.7	36.7	70.7			
Total stolon weight (g/m^2)	no rest	90.0	64.3	125.0	70.0	166.0	0.003	0.029	<0.001
	April - late May	48.0	40.7	135.7	58.7	138.3	16.81	6.92	21.03 (15.47)
	late June - early August	85.3	116.3	168.7	42.0	87.7			
Growth points on above ground stolons (number / m^2)	no rest	301	285	700	293	2198	0.015	0.025	0.01
	April - late May	276	191	1727	331	1104	278.2	162.5	406.8 (363.4)
	late June - early August	904	1333	1727	331	1104			
Growth points on buried stolons (number / m^2)	no rest	4550	3756	6846	4660	8327	<0.001	0.01	0.001
	April - late May	2610	1872	6863	3493	6353	536.8	411.0	922.6 (918.9)
	late June - early August	5356	5029	8450	2466	4028			
Total number of growth points (number / m^2)	no rest	4851	4040	7546	4953	10526	<0.001	0.016	<0.001
	April - late May	2886	2063	7521	4019	7733	639.4	516.2	1140 (1154)
	late June - early August	6260	6362	10177	2797	5131			

() SED values in brackets are for the same levels of grass.

Table 7.6 - Growth points per unit stolon length (number / m)

Grazing / cutting treatment mean	Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
		tetraploid	diploid					
46.0[a]	no rest	39.2	44.5	44.1	51.6	50.6	6.44 (5.79)	0.207
45.7[a]	April - late May	39.8	37.8	45.6	52.1	53.1		
55.9[b]	late June - early August	62.5	48.6	57.3	57.0	54.0		
SED 2.59								
F pr. <0.001	Grass mean	47.2	43.6	49.0	53.6	52.6	4.37	0.239

Table 7.7 - Stolon weight per unit stolon length (g / m)

Grazing / cutting treatment mean	Rest period	Perennial ryegrass		Meadow fescue	Cocksfoot	Timothy	SED	F pr.
		tetraploid	diploid					
0.738	no rest	0.693	0.734	0.732	0.724	0.806	0.059 (0.057)	0.333
0.779	April - late May	0.666	0.735	0.807	0.776	0.913		
0.884	late June - early August	0.856	0.878	0.948	0.842	0.895		
SED 0.0254								
F pr. <0.001	Grass mean	0.738	0.782	0.829	0.781	0.871	0.037	0.051

() SED values in brackets are for the same levels of grass.

The effect of cutting and grazing management on annual meadow grass density was consistent over all association types (tables 7.5 & 7.8). Unrested swards had the highest annual meadow grass densities show, swards rested during April too late May had reduced infestations while swards rested from mid June to early August had minimal infestations.

Table 7.8 The effect of cutting / grazing management on annual meadow grass infestation.

(Cores - November of the second grazing year)

Rest	Annual meadow grass (tillers / m^2)
no rest	2377
April to late May	1591
late June to early August	100

SED 282.8; F pr. <0.001.

The relative proportions of above ground and buried stolon were strongly influenced by grazing management (table 7.9) with the unrested swards having the lowest proportion of stolon above ground. Swards rested from late June to early August had the greatest proportion of above ground stolon.

Table 7.9 The effect of cutting / grazing management on the percentage of the total white clover stolon length which was above ground.
(Cores - November of the second grazing year)

no rest	7.69%
April - late May rest	10.61%
Late June - early August rest	15.78%

SED 1.569; F pr. <0.001.

The relative proportions of above ground and buried white clover stolon were also influenced by companion grass type (table 7.10). It was noted that over all the greatest proportion of buried stolon occurred in the tetraploid perennial ryegrass swards. At the other extreme, the greatest proportion of above ground stolon was found in the timothy swards.

Table 7.10 The effect of white clover companion grass on the percentage of the total white clover stolon length which was above ground.
(Cores - November of the second grazing year)

Perennial ryegrass (tetraploid)	8.68
Perennial ryegrass (diploid)	10.46
Meadow fescue	10.53
Cocksfoot	9.90
Timothy	17.24

SED 2.976; F pr. 0.12.

7.3 DISCUSSION

50 mm and 100 mm diameter corers have been used effectively by different workers involved in sward studies. 50 mm corers clearly have their place, particularly for tiller counts, when examining grass only swards, while Hay (1983) and Hay *et al.* (1983) used 50 mm cores for their work on white clover stolon stratification. Both types of corer were tested before the methodology for this experiment was finally established. The smaller corer also produced a less intact core, created more soil contamination of herbage and surface (and aerial) stolons had a tendency to become separated from the core. The 100 mm (golf) corers were therefore chosen as preferable for grass / white clover swards as they minimised any damage, displacement or contamination caused to stolons and tillers and at the same time reduced edge effects. It is hard to conceive how using 50 mm corers, workers could effectively distinguish between surface and aerial stolons.

Fothergill (1992 and pers. comm.) describes a technique in which randomly selected turves, 25 cm x 25 cm, are taken using a steel-edged quadrat and a spade. The soil is washed from the from the base of each turf and the clover plants carefully teased out from the vegetation mat. The number of clover plants recovered by this technique was so great that having removed plants with cut or damaged stolons he then took twenty whole plants at random for further measurements. Besides those parameters mentioned under the core assessment above, he also divided the clover plants into one of three plant orders according to degree of complexity as detailed in chapter one (Brock *et al.*, 1988). One of the main drawbacks of this technique, especially with small plots, is the damage caused to the sward / plots in removing such a large turf. The use of smaller turves is not the answer as a greater number of these would be needed, and while this would give a more representative sample it would also increase the proportion of damaged (and thus rejected) stolons thereby creating a bias in favour of lower order plants.

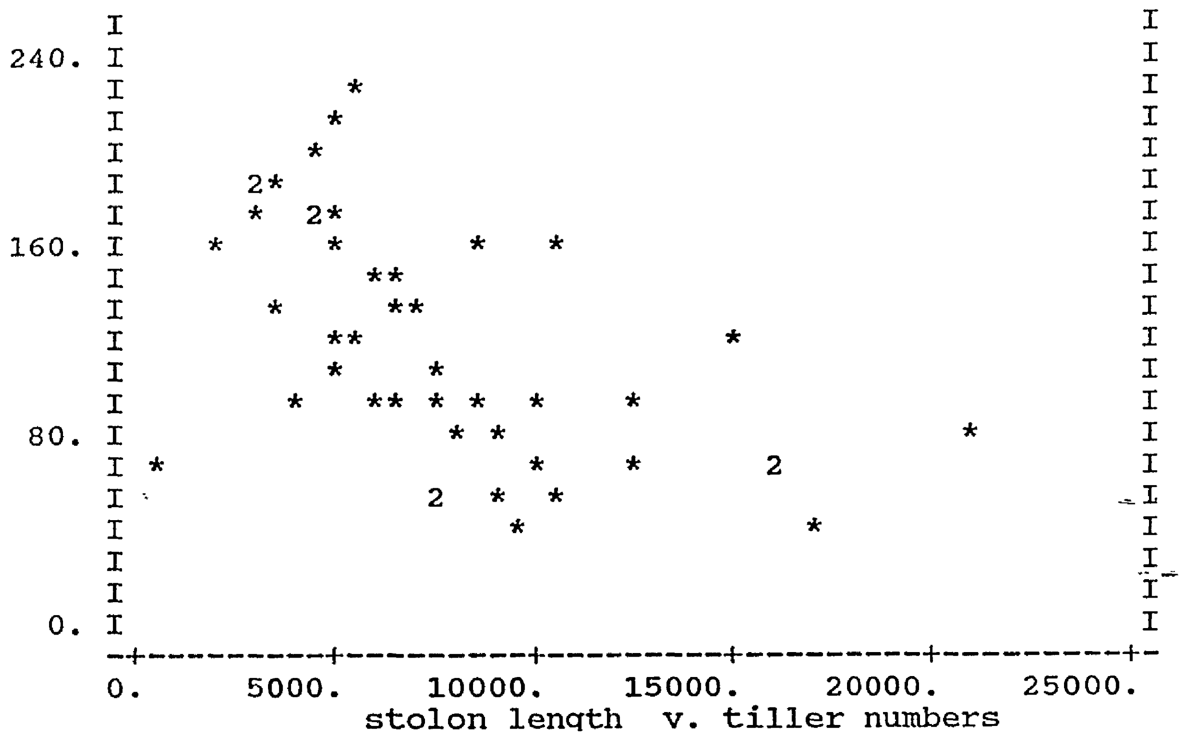
The larger plot size used in experiment 2 allowed destructive harvest and sampling methods to be used without significant long term damage to the swards or change in sward characteristics. It was considered therefore that the most appropriate method to determine the effect of both grass / white clover associations and grazing / cutting management treatments was to use cores (this technique was not used in experiment 1 as destructive methods were not considered appropriate to the small $1m^2$ plots).

Let us now discuss the results presented in the previous section. Stolon lengths recorded during establishment indicated that, the less aggressive the grass during establishment, the greater was the opportunity for white clover to establish. Thus the lowest stolon lengths were therefore found in the perennial ryegrass plots with their high tillering capacity, whereas the highest were for the low tillering rate, slow establishing timothy / white clover associations - perhaps aided by timothy's slow recovery rate after the light establishment grazings. Meadow fescue and cocksfoot which were intermediate in terms of tillering had correspondingly intermediate stolon lengths. With the tripling of white clover stolon lengths in all associations during the first winter, a significant and expected trend in sown grass tiller numbers had developed with the highest values in the diploid perennial ryegrass associations, the lowest in the timothy and meadow fescue associations, with the cocksfoot and tetraploid perennial ryegrass associations being intermediate in this regard. It must be remembered however that up to this point only strategic light grazings had been used to aid both grass and white clover establishment.

Measurements made at the end of the first treatment year, showed that white clover stolon lengths in both timothy and meadow fescue associations continued to rise, as did those in both the ryegrass associations albeit to a lesser extent. Within the cocksfoot associations however, stolon lengths remained fairly static. This, as suggested in chapter 6, may have been due to selective grazing swinging the sward balance in favour of grass. While white clover stolon lengths did not change significantly during the second winter, measurements made at the end of the second treatment year reinforced the trends observed earlier. The white clover stolon lengths in the perennial ryegrass associations had continued to increase over the year but were still considerably lower than those in the timothy and meadow fescue associations. The tetraploid perennial ryegrass / white clover association however, had only marginally more stolon than the diploid perennial ryegrass / white clover association. White clover associations with meadow fescue and timothy which had the greatest white clover stolon lengths and the lowest number of grass tillers, while

Figure 7.1 General relationship of grass tiller numbers to white clover stolon length

Graph of correlation of white clover stolon length against grass tiller number.



Stolon length	=	167.1 $\pm$(13.1) - 0.00646 $\pm$(0.00149) x number of tillers
Significance	=	0.001
Correlation coefficient	=	-0.551
Variance accounted for	=	28.7%

Analysis results for individual grasses

Grass	Correlation coefficient
Perennial ryegrass (Tet)	-0.219
Perennial ryegrass (Dip)	-0.723
Meadow fescue	-0.381
Cocksfoot	-0.176
Timothy	+0.325

associations with diploid perennial ryegrass had the greatest number of grass tillers and low white clover stolon lengths. The tetraploid perennial ryegrass / white clover association was intermediate in both respects. The white clover stolon length in the cocksfoot white clover association rose only very slightly over the year to well short of those even in the diploid perennial ryegrass / white clover association. This was despite cocksfoot tiller densities similar to tetraploid perennial ryegrass. This, once again was attributed to selective grazing of white clover in preference to the less palatable cocksfoot. Another factor might have been the greater physical size of a cocksfoot tiller, compared with those of perennial ryegrass, allowing less space for white clover development.

Sward core measurements seemed to suggest an inverse relationship between grass tiller numbers and white clover stolon length. When this relationship was tested for all the cores taken at the end of the second grazing year using regression analysis (Figure 7.1 and appendix 6) it was shown to be highly significant. However when the relationship was tested for the grass species separately, the limiting effect of increased tiller density was shown to be greatest with diploid perennial ryegrass where it accounted for 45.4% of the variation. The relationship however, was less pronounced with the other grasses. With cocksfoot, it is possible that, the combined effect of tiller number and tiller circumference imposed a limiting effect at lower tiller numbers. With timothy the analysis suggests that the reduced grazing pressure necessary to maintain timothy tiller numbers also encourages stolon development. Meadow fescue tiller density was so low as to have little effect on stolon length.

White clover stolon lengths in all associations, during the third winter, were reduced to at least half the November length and to a third of the November length in the case of the diploid perennial ryegrass. This reduction in white clover stolon length may have resulted from a stolon mat comprised of a large proportion of lower order plants. These plants may have had insufficient reserves to survive the winter (Fothergill and Davies, 1993).

In July of the third post establishment year (during which continuous sheep stocking was continued) a further and final core assessment was made. While there were no other July values with which to compare the results, it was noticed that white clover stolon lengths rose in all but the perennial ryegrass associations. However, it could well have been the case that white clover stolon lengths would have risen later in the year once the late summer pattern of white clover development had taken its effect or if the swards had been rested for a conservation rest.

A great reduction was noted in meadow fescue tiller numbers in the late rested treatment by the end of the second grazing year with a further, dramatic reduction by July of the third year. This suggests therefore that meadow fescue in association with white clover is not persistent enough to withstand continuous stocking with sheep and it was also noted that the imposition of a rest for a conservation cut, whatever its timing did little to improve the situation. Also noted was that at the low tiller densities in the meadow fescue / white clover associations, high white clover stolon lengths appeared to be unaffected by rest management treatment.

End of second treatment year white clover stolon lengths in tetraploid perennial ryegrass swards were reduced (although not significantly) by any rest for a conservation cut. This was probably because the tetraploid grass was too aggressive when allowed to become taller. This adverse effect on white clover stolon length was greatest when the sward was rested during the period from April till late May. In the case of diploid perennial ryegrass, the late June to early August rest allowed white clover stolon to increase to lengths greater than in the tetraploid swards. Once again, white clover stolon lengths were significantly lower in diploid swards that were rested during April to late May. These responses in terms of white clover stolon length are probably related to the effect which the grazing / cutting policies have on ryegrass tillering rather than a direct effect of the management on the white clover. With regard to the tetraploid, the tiller number was increased by an early rest and reduced by the later rest, whereas with the diploid, tiller number was only slightly reduced by an early rest so that severe competition and shading adversely influenced white clover stolon length. With both timothy and cocksfoot, any rest for a conservation cut had an adverse effect on white clover stolon length. In both cases the later rest had the most severe effect. In the case of timothy, its slow recovery under grazing, particularly at the time of peak white clover stolon development, allows unrestricted growth of white clover. When rested, competition from the grass inhibits white clover stolon development. With regard to cocksfoot, deep rooting habit and consequent ability to grow vigorously in mid summer could well afford it a competitive advantage at that time which it would not have in a grazing situation.

With regard to the number of white clover stolon growth points per unit length a similar pattern was observed. Where competition from grass was greatest, the number of growth points per unit length was lowest. Thus, with both ryegrasses and meadow fescue, the mid to late summer rest, which is associated with low tiller numbers, yielded the highest number of white clover stolon growth points. Conversely with both timothy and cocksfoot, continuous stocking afforded the least competition to the white clover so that a greater number of white clover growth points developed. When stolon dry weight per unit length was examined, an identical pattern was observed, showing once again, that increased competition from grass resulted in lower white clover stolon dry weights per unit length. It is reasonable to argue that this is in agreement with the findings of Hay *et al.* (1983). While they did not compare companion grass species, they did study the effects of different sheep grazing managements on white clover stolon length per unit weight. The sheep grazing management treatments used were continuous stocking, rotational grazing and a combination of rotational and continuous stocking. Predictably, these grazing treatments produced large and significant differences in grass tiller densities. It follows therefore that swards with the greatest tiller densities imposed the greatest competition effect on white clover. On this basis their results confirm that increased competition from grass results in greater lengths per unit dry weight (lower dry weights per unit length) of white clover stolon.

The overall effect of companion grass type on the abundance of annual meadow grass in the sward was seen in a consistent trend over the three years with an inverse relationship between annual meadow grass tiller number and sown grass tiller number. Thus diploid perennial ryegrass with the greatest tiller density had the lowest annual meadow grass infestation. Tetraploid perennial ryegrass, cocksfoot, timothy and meadow fescue had progressively lower tiller densities and correspondingly greater annual meadow grass tiller densities. By the third summer, by which time meadow fescue tiller numbers had collapsed, the annual meadow grass tiller density had risen dramatically. The effect of cutting and grazing management on annual meadow grass density was consistent over all association types. Unrested swards had the highest annual meadow grass densities, swards rested during April too late May had reduced infestations while swards rested from mid June to early August had minimal infestations.

The limited number (2 per year) of core assessments meant that it was not possible to investigate the fluctuations in the balance of above ground and buried white clover stolon as they occurred throughout the season. The results do confirm, however, the findings of Hay (1983) and Hay *et al.* (1983) that there was a greater proportion of buried stolon at the end of the winter (March) than pre-winter (October / November).

The relative proportions of above ground and buried stolon were strongly influenced by grazing management with the unrested swards having the lowest proportion of stolon above ground. Swards rested from late June to early August had the greatest proportion of above ground stolon, which could reflect the type of stolon development during late summer or simply a shorter period of time since the prolific mid to late summer stolon growth for the stolon to be trampled and consequently buried. Hay *et al.* (1983) found that sheep grazing management had little effect on the spatial distribution of white clover stolon. They did not, however, include a conservation rest treatment within their management options.

The relative proportions of above ground and buried white clover stolon were also influenced by companion grass type. It was noted that over all the greatest proportion of buried stolon occurred in the tetraploid perennial ryegrass swards. This is probably due to two reasons. Firstly, its open sward and upright growth habit allows easy stolon burial. Secondly, the high stocking rates which it can support must increase trampling and therefore stolon burial. It was noted during the third grazing year, that during the extremely wet spring of 1992 that sheep had to be removed from the tetraploid perennial ryegrass swards because of soil contamination on the herbage. At the other extreme, the greatest proportion of above ground stolon was found in the timothy swards with their tiller numbers.

7.4 CONCLUSIONS

1. White clover establishment was poorer in the quick establishing / tillering perennial ryegrass associations and better in the slower establishing cocksfoot, timothy and meadow fescue associations.

2. By a year after sward establishment, timothy and meadow fescue proved to be greatly superior to perennial ryegrasses, and ideal companion grasses for white clover, in terms of sward white clover content. Cocksfoot proved to be inferior to perennial ryegrasses in this regard. Tetraploid perennial ryegrass sward contained slightly more white clover than diploid perennial ryegrass / white clover swards.

3. By the end of the second full grazing year, tiller densities were greatest with diploid perennial ryegrass followed in descending order by cocksfoot, tetraploid perennial ryegrass, meadow fescue and timothy.

4. By the summer of the third grazing year, the meadow fescue and to a lesser extent, the cocksfoot components of their respective associations had fallen probably due to lack of persistence under continuous sheep grazing.

5. White clover stolon length in diploid perennial ryegrass / white clover associations was reduced when given an April to late May rest but enhanced when given a late June to early August rest.

6. Number of white clover growing points, white clover stolon length and white clover stolon weight per unit length were inversely related to grass tiller number (ie. competition from grass).

7. Annual meadow grass tiller numbers were inversely related to sown grass tiller numbers.

8. Swards rested from late June to early August had the greatest proportion of above ground stolon.

9. The greatest proportion of buried stolon was in the tetraploid perennial ryegrass / white clover association with its comparatively open sward, high stocking rates and erect growth habit.

10. The lowest proportion of buried stolon was in the timothy / white clover association with its more prostrate growth habit and lower stocking rates.

11. With by much the larger proportion of white clover stolons being buried in all associations, no clear pattern was observed between stolon burial and survival.

CHAPTER 8

GENERAL DISCUSSION AND CONCLUSIONS

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INTRODUCTION

Claims that grass / white clover based systems have proved to be impracticable due to the unreliability of the white clover component of the sward (Aldrich, 1972, Wolton, 1972, and Frame and Newbould, 1984) led to an appeal by Laidlaw and Frame (1988) for further work to be initiated in this area. It has been shown however, that zero fertiliser nitrogen systems, based on grass / white clover swards can be operated successfully for dairy cows by Bax (1990) and for beef cattle by Younie *et al.* (1986) and Younie (1992). Continuous stocking has been adopted in these systems as it minimises the possibility "bloat" which might arise in a rotational grazing system where cattle are presented with a flush of lush rested white clover. Also, for lamb production Swift *et al.* (1990; 1992a, b & c; 1993) have demonstrated that grass / white clover based systems can be viable and this current work provides data of a strategic nature which supports their work and generally provides a basis for systems development.

Rotational grazing has been shown by Calder (1970), Korte and Parsons (1984), Newton *et al.* (1985) and Johnson *et al.* (1990) to be the best grazing management strategy for sheep on grass / white clover swards. Nevertheless, such systems tend to be labour intensive requiring high initial costs which are disproportionate to the profitability of the enterprise. Continuous stocking systems are generally the preferred management option. The combined effects of hard continuous stocking (Laidlaw and McBratney, 1983 and Curll and Wilkins, 1985 and selective grazing (Ridout and Robson, 1991 and Woledge *et al.*, 1992b) have sometimes led to diminished white clover presence in continuously, sheep grazed grass / white clover swards. Various strategies aimed at increasing the proportions of white clover in grass / white clover swards under continuous stocking with sheep, which involve a reduction of grazing pressure for a period of time, have been investigated. These included - reduced stocking rates (Curll, 1982 and Curll *et al.*, 1985a and 1985b), a switch from sheep to cattle grazing (Monteath *et al.* 1977), a change from continuous stocking to rotational grazing (Marsh and Laidlaw, 1978, Laidlaw and McBratney, 1983 and Newton *et al.*, 1984), a rest for a conservation cut (Wolton *et al.*, 1970, Wilman and Asiegbu, 1982 and Curll and Wilkins, 1985) or the removal of stock for a few weeks with the accumulated herbage being grazed at the end of the rest (Davies and Jones, 1988). With perhaps the exception of the latter, these strategies gave a long term increase in the sward white clover component. However the timing, severity and subsequent managements of the treatments resulted in various degrees of success.

Davies (1989) however, showed that another method of maintaining an agriculturally effective balance between grass and white clover in mixed swards was to gain an understanding of the different growth and survival strategies of perennial ryegrass and white clover.

The main aim of this work, therefore, was to investigate sward component and management factors which influence the reliability of grass / white clover swards. While this work gave several opportunities to examine the related issues of canopy architecture and herbage utilisation under grazing, which have been discussed earlier, this discussion is restricted to the main hypotheses. In both of the experiments reported in this thesis, two hypotheses were tested.

1. **The white clover component of a continuously sheep grazed grass / white clover sward is enhanced by the imposition of a rest from grazing for a conservation cut.**

2. **The presence and survival of white clover in a continuously stocked grass / white clover sward is determined by the specific / varietal characteristics of the sward components and their combined response to management.**

8.1 HYPOTHESIS 1

Results show that the management determinants of the amount of white clover present in a continuously sheep grazed, grass / white clover sward can be divided in two main groups. Firstly, those which impose a direct effect on the white clover and secondly those which affect the companion grass and thus alter the white clover / companion grass balance so indirectly influence the white clover. With regard to the former, it was noted that a rest from sheep grazing at the time of peak white clover growth from mid to late summer encouraged white clover stolon development to provide a strong stolon network capable of survival through the winter. This was in line with the results of work by Curll and Wilkins (1985) who found that when rested from continuous stocking, white clover stolon length, petiole length and leaf diameter increased while leaf and node number per unit length decreased. It was also noted, that the use of smaller leaved white clover types likewise produced a dense stolon mat as described by Evans and Williams (1987), which for the most part escaped grazing and ensured persistence. With regard to the indirect effects, it was generally observed that treatments which encouraged a more open growth habit on the part of the companion grass and therefore less competition for light and space, enhanced the white clover content of the sward. These treatments include:

. the use of companion grass species which produce open swards such as timothy or meadow fescue;

. the use of companion grasses whose varietal characteristics encourage openness of sward such as tetraploid perennial ryegrass as advocated by Swift *et al.* (1993) or earlier maturing varieties;

. the use of acceptable grasses like timothy or perennial ryegrass rather than coarse grasses like cocksfoot, the rejection of which (or simply preference for white clover) can lead to grass dominance and the detriment of white clover;

. strategically timed rest periods from continuous sheep grazing - continuous stocking by sheep fosters tillering of the companion grass to the competitive disadvantage of white clover, particularly with densely tillering diploid perennial ryegrass (Curll and Wilkins, 1985).

With grasses like early maturing perennial ryegrass, an early rest should be avoided as the competition for light is so intense due to the onset of reproductive growth on the part of the grass with associated stem elongation and sub optimal temperatures for white clover growth (Davies, 1992). The white clover will respond with longer petioles and larger leaves, but the long term effect on white clover survival is damaging especially with large leaved types.

The white clover enhancing management treatments, outlined above, are based on a knowledge of the different and largely complementary seasonal growth patterns of grass and white clover which contribute to the dynamics of the sward as highlighted by Davies (1989) and knowledge is used to select treatments which effect immediate and longer term changes in sward structure.

The understanding of the importance of white clover leaf size to the quantity of white clover in both the short and longer term, and of its effect on the impact of a conservation rest was one of the major outcomes of this work. The imposition of a conservation rest was shown to influence the effect of white clover leaf size on long term white clover presence and cover. With small leaved white clover, white clover levels were high regardless of the management treatment applied. With the large and very large leaved white clovers, however, the larger the leaf size, the greater was the harmful effect of an April to late May rest and the greater the benefit to white clover of a July to mid August rest. This was considered important as the large leaved white clovers are intended mainly for use in conservation type swards where the long petioles and large leaves afford the white clover an opportunity to compete with the companion grass for light. The problem possibly lies with the growth habit of these larger leaved varieties, where the stolons have few branches and, especially within conservation swards, the stolons do not grow in close proximity to the ground surface. This results in a proportion of the stolon being cut while the remaining stolon is vulnerable to subsequent grazing. Under a cutting and grazing regime, particularly where sheep are involved, these larger leaved white clovers are less persistent. This is supported by work reported by Wilman and Asiegbu (1982b) who expressed the view that medium / large leaved varieties of white clover could with advantage be defoliated rather less frequently than small leaved varieties. They also noted that small leaved varieties had thinner stolons than medium / large leaved varieties but about twice the stolon length and a relatively high proportion of small leaves which escaped defoliation.

These results suggest that very large leaved white clovers are not suitable for any regime which involves continuous stocking with sheep. Small leaved white clovers on the other hand are ideal for continuous stocking with sheep with densities being little affected by the imposition of a rest for a conservation cut. Medium leaved white clovers in association with perennial ryegrass are ideally suited to a mixture of cutting and grazing with levels generally being enhanced by a late June to early August rest.

With regard to the contribution of white clover to the conservation cuts, it was observed in experiment 1 that in all three cuts over both years, the highest yields of herbage dry matter were from the small leaved white clover / perennial ryegrass associations. These results show an opposite trend to that found by Widdup and Turner (1983) and Boyd and Frame (1987) where yields of both total herbage and of white clover were directly related to white clover leaf size. The main difference between their experiments and those reported here was that current experiments the main management treatment was continuous sheep grazing as opposed to periodic cutting to simulate defoliation under rotational grazing. Using white clover transplants inserted into grass populations, Baines *et al.* (1983) however, found that under cutting the large leaved white clover / grass associations initially yielded more than small leaved white clover / grass associations, but these latter associations ultimately gave the greater yields due to the superior persistence of the smaller leaved white clover types.

As discussed in chapter 4, small leaved white clovers responded to continuous sheep grazing with the production of a dense stolon mat (Davies,1970, Munro *et al.,* 1975, Baines *et al.,* 1983 and Frame and Newbould, 1986) which was capable of a rapid response in terms of growth point and leaf production as soon as a rest was imposed (Davies and Jones, 1988). This should be considered along with the conclusion stated earlier, that longer term, small leaved white clovers, in terms of cover and presence, were relatively unaffected by the rest treatments. This suggests that in situations where continuous stocking with sheep is part of the management regime, small leaved white clovers should be considered regardless of whether or not the sward might be used for a conservation cut. Among the other leaf size categories, the very large leaved white clover associations gave the highest yields at first cut, whereas, the medium and large leaved associations performed better at second and third cuts. This was attributed to the very large leaved white clovers having had a competitive advantage within the taller first cut canopy. In general, the differences in total herbage dry matter were largely attributed to the differences in the white clover contribution to the herbage yield. A clear pattern was observed that related increased proportion of white clover dry matter to later cuts and smaller leaved types.

Any discussion on the dynamics of a continuously sheep grazed grass / white cover sward is incomplete without the mention of the effects of stocking intensity or frequency of defoliation which were not fully investigated within the current experiments (albeit experiment 1 was subjected to severe grazing pressure whereas experiment 2 had stocking levels nearer to those normally advocated). Measurements made under hard grazing showed a reduction in leaf size, petiole length, growth point number and trifoliate leaf numbers compared with rested swards as shown by Curll and Wilkins (1985) who also noted that the greater the grazing pressure the greater the reductions. Likewise Wilman and Asiegbu (1982b) noted that increasing the interval between defoliations resulted in increases in stolon length per unit area, stolon diameter, petiole length, weight of leaf and numbers of leaves present. Laidlaw (1991) while admitting the importance of defoliation, stressed the role of light and in particular of an increasing red : far red ratio in the initiation of bud and therefore growth point development. This raises the possibility of two conflicting trends. Firstly, grazing of white clover reduces stolon growth and branching and secondly, a rest from grazing increases the possibility of shading which can likewise reduce stolon development and branching. A balance must therefore be attained between the harmful effects of grazing and those of shading. This balance is influenced by a number of interacting factors:

* severity of grazing and associated effects on
    . grass tiller density
    . stolon reserves and growth point numbers
* grass species / variety characteristics and associated effects of:

- . seasonal growth pattern
- . tiller density and tiller size (circumference)
- . palatability

* rest timing with regard to:

- . grass and white clover seasonal complementation
- . vegetative or reproductive grass growth

* white clover varietal characteristics in terms of

- . leaf size
- . aptitude for stoloniferous growth
- . branching potential

* sward condition at any point in time with regard to:

- . grass tiller density
- . white clover stolon reserves
- . growth point numbers
- . time of year
- . soil fertility

8.1.1 Conclusion

Clearly it is too simplistic to recommend one sward composition formula or management strategy for all situations. Rather, the best mix of sward components should be selected for each situation and a flexible management system adopted which requires a minimum of management, labour and capital input, which can be modified as required to meet livestock and sward manipulation requirements.

With regard to the hypothesis **that the white clover component of a continuously sheep grazed grass / white clover sward is enhanced by the imposition of a rest from grazing for a conservation cut,** the works shows:

a. that while there are situations where this strategy is highly effective, there are also situations in which the advantage to the white clover sward component is minimal or even where the treatment disadvantages the white clover;

b. that the success or failure of the strategy is determined by the timing of the imposed rest.

The results of this investigation confirm the conclusions of Grant and Barthram (1991) that in continuously stocked perennial ryegrass / white clover swards, the incorporation of appropriately timed rest periods from grazing, followed by cutting (silage cuts) can provide a means of enhancing white clover content and performance. This work also expands, explains and identifies their phrase "appropriately timed" and investigates and describes the contention implicit in their work that the effect of and optimum timing of the rest is influenced by the characteristics of the sward components.

8.2 HYPOTHESIS 2

Let us now consider:

1. the composition of grass / white clover swards with regard to the specific and varietal characteristics of the components and their interactions;
2. the response of these respective associations to continuous sheep grazing and imposed rests both in terms of the yield and botanical and chemical composition of the conservation crop and subsequent sward condition and composition.

8.2.1 Perennial ryegrass / white clover associations

The effect of continuous stocking by sheep on perennial ryegrass was to stimulate tillering. The effect was greater with the diploid perennial ryegrass than with the tetraploid perennial ryegrass, so more white clover developed in the tetraploid sward. With regard to the perennial ryegrass / white clover associations differences in the degree of response to the conservation rest, and more particularly to its timing, were observed between tetraploid and diploid associations. In the case of the diploid, an early rest, April to late May greatly reduced the white clover component of the sward whereas the mid to late summer rest allowed white clover levels to rise to levels comparable with those in the tetraploid swards. With tetraploid perennial ryegrass / white clover associations the same overall trends were observed, although to a lesser degree. A probable explanation is as follows. During the period April to late May, perennial ryegrass growth was at its peak with rapid tiller production followed by internode elongation. This intense competition from the ryegrass during this period of slow white clover development, resulted in a significant long term reduction in the abundance of white clover in the sward. This effect was greatest in the more densely tillered diploid perennial ryegrass swards. A rest for a conservation cut during late June to early August resulted in a reduction of perennial ryegrass tillers, especially in the case of the diploid, so that the white clover had an opportunity during its time of peak production and of the mid summer trough in perennial ryegrass growth. This reduction in tiller numbers was greatest in the case of the diploid perennial ryegrass. These conclusions are supported by the inverse relationship between diploid perennial ryegrass tiller number and white clover performance discussed in chapter 7.

In general it was found that white clover contents in tetraploid perennial ryegrass / white clover associations were such that no white clover enhancing treatments would have been necessary in practice. This confirms the findings of Swift *et al.* (1992c), who found no problem in maintaining white clover levels under continuous sheep grazing using tetraploid perennial ryegrass in association with small leaved white clover for a period in excess of five years. Given diploid perennial ryegrass and perhaps a medium leaved white clover a white clover enhancing rest may have been desirable.

Interactions between the imposition and timing of conservation rest and perennial ryegrasses of close maturity ratings were harder to differentiate. However it was noted in experiment 1 that the beneficial effect of a July to mid August rest and the harmful effects of an April to late May rest were greatest in the early and very early perennial ryegrass / white clover associations. While it must be said that, perennial ryegrass maturity was not one of the sward characteristics being investigated in experiment 2, Merlinda, which was the chosen tetraploid variety, was ten days earlier than the diploid Magella, albeit both were intermediate varieties. This difference of ten days does not seem to be great enough to effect the interaction of ploidy and rest treatment indicated above. It is important therefore that any comparison between diploid and tetraploid varieties of perennial ryegrass is between varieties of similar maturity as large differences between maturity ratings were shown to have a greater impact than differences in ploidy as demonstrated by Davies *et al.* (1991).

Results from experiment 1 show a consistent trend of a decreasing proportion of white clover in perennial ryegrass / white clover swards from very early through early and intermediate to late perennial ryegrass associations. This was probably due a combination of two factors. Firstly, the earlier varieties of perennial ryegrass had a complementary rather than competing seasonal growth pattern (Haynes, 1980 and Davies, 1992). The greatest shading occurred at a time when it would have the least adverse effect on white clover and which allowed white clover to develop later in the season at its time of peak production potential. Secondly, and probably the more important factor was that later varieties of perennial ryegrass had a greater tillering capacity which inhibited white clover development.

With the conservation cuts, themselves, experiment 1 results indicated that diploid perennial ryegrass associations gave the highest total herbage dry matter yields at first cut in both years while no clear pattern was observed with subsequent cuts. On the other hand, in experiment 2, the tetraploid perennial ryegrass / white clover associations consistently outyielded the diploid perennial ryegrass associations in both early and later cuts over both years, although much of this yield advantage, at least at first cut, was probably due to the earliness of the tetraploid. The higher yield of the tetraploid perennial ryegrass / white clover association at first cut was mainly due to the ryegrass component whereas its superiority at second cut was principally due to the white clover component. With regard to the influence of perennial ryegrass ploidy on the white clover content of the herbage dry matter, no highly significant trends were observed in experiment 1. However, the herbage from the tetraploid perennial ryegrass associations had higher white clover percentages than the diploid associations. In experiment 2, the white clover contribution to the tetraploid perennial ryegrass association yield was small compared with that of the diploid perennial ryegrass / white clover association with the position reversed at the later cut. These findings suggest on balance that the tetraploid perennial ryegrass associations cut for conservation contain greater white clover proportions than diploid perennial ryegrass associations but confirm the observation made earlier, that large differences in maturity often have a greater influence than ploidy.

8.2.2 Cocksfoot / white clover associations

The cocksfoot variety Prairial, used in experiment 2, was well adapted to hard grazing with relatively high tiller numbers being retained throughout, unlike traditional cocksfoot varieties whose upright growth habit leads to slow recovery after defoliation and subsequent reduced vigour (Haynes, 1980). Tiller number was relatively unaffected by the management treatments applied. However, competition during rests for conservation cuts resulted in lower white clover stolon lengths. The April to late May rest had a more adverse effect on white clover stolon length than did the late June to early August rest. The fact that white clover stolon length did not increase with a the later rest was probably due to the deep rooting nature of cocksfoot making it a very efficient competitor in dry mid to late summer conditions. It would appear therefore that the best way to maintain white clover levels in a cocksfoot / white clover association is to continuously stock the sward to prevent the grass from becoming too long and coarse. The continuously stocked cocksfoot / white clover sward contained less white clover than the tetraploid perennial ryegrass association and was unable to respond, in terms of white clover stolon length, to the late June to early August rest.

Cocksfoot / white clover conservation yields for the first cut in the first year showed that the proportion of white clover in the total dry matter yield was only exceeded by that of the timothy / white clover association. Although both these grass / white clover associations had the lowest total herbage yields at this cut, they also had the highest white clover yields. Their high white clover contents was probably due to the lack of competition from relatively open swards. The large proportion of white clover in the cocksfoot / white clover association was not sustained into the second year. This is in keeping with the observations of Chestnutt and Lowe (1970), who while admitting that in general, there is evidence of an inverse relationship between white clover yield and that of associated grasses (Cowling and Lockyer, 1965), concede that cocksfoot shows an aggressiveness to white clover out of proportion to its yielding ability. This may be, at least in this experiment, as a result of selective grazing to the detriment of the white clover allied with vigourous cocksfoot growth at times of soil moisture deficit. These factors suggest that cocksfoot is not an appropriate companion for white clover, especially under sheep grazing and cutting management.

The observations with regard to the place of cocksfoot in mixtures with white clover are in agreement with those of researchers who generally regard cocksfoot the least compatible as a companion grass of the common agricultural grass species (Chestnutt and Lowe, 1970 and Baines *et al., 1983*).

8.2.3 Timothy / white clover associations

Timothy / white clover associations on the other hand, had the highest white clover stolon lengths of all the grass / white clover associations in the continuously stocked, unrested, treatment. Timothy tiller numbers rose consistently over the experimental period and were highest in the continuously stocked, unrested , treatment. This occurred regardless of "bulb pull" (plate 6.18). The rest treatments, however gave a considerable reduction in white clover stolon length with the April to late May treatment reducing the white clover stolon length by 25% and the late June to early August treatment reducing white clover stolon length by over 50%. Timothy tiller numbers were slightly reduced (4.8%) by the April to late May rest and by 23% with the late June to early August rest. It is possible that the later seasonal production of the timothy minimised the adverse influence of competition at the April to late May rest, whereas the later production and intense shading from this broad leaved grass at the time of peak white clover production, disadvantaged the white clover. In other words, the seasonal growth patterns of timothy and white clover are less complementary with both species being comparatively late. Even in the late rested sward however, white clover stolon length was still at 96.7 m/m^2 at the end of the second treatment year. Part of the success of both the timothy and white clover components of this association may be due to the relatively low herbage productivity from this association as measured by both exclosure cage and livestock unit grazing days techniques, with stocking rates, at times, having to be very low in order to maintain a 60 mm sward surface height.

The results of experiment 2 show clearly that timothy is fully compatible with white clover under the management systems tested and in terms of white clover development and survival is an ideal white clover companion grass. These findings are in agreement with those of Hughes (1951), Hunt (1960), Martin (1960), Reid (1961), Bland (1968), Baines *et al.* (1983) and Lex and Simon (1991) but conflict with those from the majority of sources reviewed and supported by Chestnutt and Lowe (1970).

With regard to the conservation cuts, high placings of timothy / white clover in terms of dry matter yield, "D-value" and soluble carbohydrates were noted. Lower white clover percentages arising from high grass yields rather than low white clover yields resulted in low crude protein levels. While this experiment cannot be compared directly with the cutting experiment of Frame and Harkess (1987) it is worthy of comment that they found the timothy / white clover sward the highest yielding in two out of three years when comparing conservation yields of tetraploid perennial ryegrass, diploid perennial ryegrass, meadow fescue and timothy associations with white clover and other forage legumes.

8.2.4 Meadow fescue / white clover associations

The meadow fescue / white clover association like the tetraploid perennial ryegrass / white clover association had its highest tiller densities in the swards rested during April to late May. This may well have been due to the earlier maturity of these two grasses. Tiller density in the late June to early August rested meadow fescue / white clover association was only 39% of that in the early rested sward, compared with the unrested, continuously stocked sward with 70%. However , the latter sward had its tiller density reduced to 764 tillers / m^2 by July of the third grazing year. The total white clover stolon lengths in the meadow fescue / white clover swards were relatively unaffected by the grazing / cutting treatments, with all treatments around 170 m/m^2. It was observed increasingly throughout the experiment that the sward was so open that many tillers within the grazed treatment successfully produced short flowering heads while the sheep grazed the lateral leaves on the flowering stems. Harkess *et al.* (1974), investigating the role of meadow fescue, found it to be a poor competitor when mixed with grasses with high tillering capacities like perennial ryegrass. In such mixtures, meadow fescue tiller numbers were halved by the end of the first year. They did however conclude that meadow fescue was compatible with white clover and in mixtures of white clover and timothy. These present results suggest that in the longer term meadow fescue cannot stand intensive, continuous sheep grazing. The inability of this grass to maintain a dense sward into the fourth year suggests its unsuitability as a long term companion grass for white clover for continuous stocking with sheep.

Similarities between meadow fescue and tetraploid perennial ryegrass were also observed in the conservation cuts. First cut yields of total herbage dry matter were largely influenced by grass maturity as demonstrated by the high first cut yields of meadow fescue and tetraploid perennial ryegrass.

Second cut yields of total herbage were related to:

- differences in grass / white clover seasonal production patterns - thus comparatively higher yields from timothy / white cover associations than from meadow fescue white clover associations;
- the grasses response to water availability - this promoted yield of cocksfoot, and reduced yields of perennial ryegrass especially in times of drought.

Tetraploid perennial ryegrass / white clover and meadow fescue / white clover were the highest yielding associations in three out of the four cuts. These two grass / white clover associations also had the highest proportions of white clover at second cut. Nevertheless, while the meadow fescue / white clover association had a large proportion of white clover in the first cut, this was not the case in the tetraploid perennial ryegrass / white clover association first cut which was composed mainly of grass. Unfortunately, the tiller density in the meadow fescue / white clover association in July of the third year suggests that its high level of productivity might not have been sustained into the third year. These findings are in line with workers in this field (Chestnutt and Lowe, 1970 and Baines *et al.*, 1983) who are agreed that meadow fescue is highly compatible with white clover but its lack of persistence and poor long term production make it a poor choice as a companion grass for white clover. When white clover dominance and associated lack of grass persistence occur in New Zealand, perennial ryegrass is direct drilled into the sward.

8.2.5 Quality of conserved herbage

Perennial ryegrass / white clover associations gave the highest digestibility values for the late May cuts, whereas timothy produced the highest values for the early August cuts. This corresponded to the soluble carbohydrate ratings. Similarly, the cocksfoot / white clover associations consistently had the lowest digestibility values for both cuts, which corresponded with it having the lowest soluble carbohydrate values. As might be expected, in highly digestible forage, where crude protein levels were higher, soluble carbohydrate levels tended to be lower. This was demonstrated clearly in the case of the perennial ryegrass / white clover associations, where first cut crude protein levels were lowest while the soluble carbohydrate levels were the highest. However, no similar trend was observed in with the cocksfoot / white clover associations, where digestibility levels were poorer. It seems probable that crude protein levels in the conserved herbage are, at least partly, related to the proportion of white clover to grass in the herbage. Unfortunately, in this experiment we do not have separate grass and white clover analysis. However, Bax and Niessan (1992) who regretted that general expectations of high crude protein levels in silage from grass / white clover swards were not realised with primary growth herbage, also showed the white clover from this herbage had low crude protein levels. It is possible that this can be attributed to the dilution of crude protein with the production of longer petioles and larger leaves, induced by tall primary grass growth.

8.2.6 Annual meadow grass infestation

The imposition of a rest from continuous stocking was observed to have a dramatic and highly significant effect on annual meadow grass infestations in all associations. The continuously stocked, unrested swards had the most severe infestations while the swards rested late June to early August were practically free from the weed. Infestations in the continuously stocked, unrested, swards and the swards rested during April to Late May were inversely related to sown grass tiller density.

8.2.7 Conclusion

With regard to the hypothesis that **the presence and survival of white clover in a continuously stocked grass / white clover sward is determined by the specific / varietal**

characteristics of the sward components and their combined response to management. the work shows that the degree of response and agronomic benefit, if any, from the treatment are determined by the characteristics of the sward components and by the sward density and balance of the sward components prior to the rest. The important variables were shown to be the species and varietal characteristics of the grass (maturity group and ploidy), the type of white clover (leaf size) and the interactions of the possible grass / white clover combinations.

8.3 PRACTICAL IMPLICATIONS

From the results of the experiments it would be reasonable to conclude that the best type of sward to maintain good white clover levels under continuous and intensive stocking with sheep while at the same able to give excellent yields of good quality silage would be an early / intermediate tetraploid perennial ryegrass in a mixture with a small leaved white clover or a small plus a medium leaved white clover. Where a conservation cut is not envisaged as part of the management, and grazing controlled to the extent that inflorescences were never allowed to develop, the maturity of tetraploid perennial ryegrass would have little effect. If however there is a lax grazing in early season then an intermediate to late tetraploid perennial ryegrass should be chosen. It must be said however that in wet conditions and a few heavier soil types, this type of open sward is particularly susceptible to poaching and soil contamination of herbage. In such latter conditions, a diploid perennial ryegrass / white clover sward could be considered, or a blend of diploid and tetraploid perennial ryegrass but one would have to consider the possibility if necessary of imposing a late June to early August conservation rest to maintain the proportion of white clover in the sward. In a more extensive situation, a timothy / white clover sward could provide, highly palatable, clover-rich grazing with the opportunity of a large highly digestible early August silage cut. This type of sward would also be appropriate for wetter conditions as it tends to have a better "sole" than a tetraploid perennial ryegrass sward. Care would have to be taken not to over-graze the sward in order to avoid extensive "bulb pull". The main drawback with meadow fescue as a companion grass was its lack of persistence and poor tillering qualities under the management systems tested. While a straight meadow fescue / white clover sward could not be recommended, there may be a place for its use in a traditional timothy / meadow fescue / white clover mixture. However such mixtures were outwith the scope of this project. With regard to cocksfoot / white clover associations, their poor showing in terms of white clover development and proportions, and quality of conserved forage, would disqualify them for most situations. There may however be a place for such swards on light sandy soils in dry situations. In such cases, continuous stocking with sheep is the most appropriate of the management systems tested.

It is worthy of note however, that in other countries where perennial ryegrass is not sufficiently winterhardy there has to be a reliance on timothy, cocksfoot and meadow fescue. Research therefore has to reflect this and investigate the possible integration perennial ryegrass into such swards and the development of sward surface height guidelines for the non-ryegrass grass species

8.4 SUMMARY OF MAIN CONCLUSIONS

* Continuous sheep grazing of grass / white clover swards does not necessarily have an adverse effect on the survival / or maintenance of satisfactory proportions of white clover in the sward. Using small leaved white clover under intensive grazing, to a sward surface height of 45 mm, high sward white clover proportions can be maintained. At a sward surface height of 60 mm, satisfactory white clover proportions can also be achieved using medium size leaved white clover in association with each of, tetraploid perennial ryegrass, diploid perennial ryegrass, meadow fescue, cocksfoot and timothy.

* An April to late May rest from continuous sheep grazing, for a conservation cut, may greatly reduce the proportion of white clover within associations of these perennial grasses with medium sized leaf white clover, except in the case of meadow fescue where the reduction, though possibly present, may be small. Within perennial ryegrass / white clover associations, this reduction is greater with the diploid than the tetraploid and increases with both white clover leaf size and lateness of perennial ryegrass.

* In tall grass canopies as in swards rested during April to late May for a conservation cut, white clovers, including the small leaved types, respond to shading by producing longer petioles and larger lamina which are held in a narrow band high in the canopy.

* After an April to late May rest, larger leaved varieties are less able to survive a return to continuous stocking probably due to their poorer stolon reserve.

* A July to mid August conservation rest enhances the proportion of medium sized leaf white clover in the diploid perennial ryegrass association, has little effect on the meadow fescue / white clover association and reduces the proportion of white clover in tetraploid perennial ryegrass, cocksfoot and timothy associations.

* High grass population density, which is common in diploid perennial ryegrass swards under continuous stocking can limit white clover development. In similarly grazed tetraploid perennial ryegrass swards, the sward is open enough to allow the maintenance of satisfactory proportions of white clover.

* With continuously stocked meadow fescue / white clover associations, the sward is so open that white clover becomes dominant and survival of the sown grass is jeopardised.

* With continuously stocked cocksfoot / white clover swards, the combined effects of tiller number, tiller size and coarseness, and selective grazing of white clover limit white clover development.

* With timothy / white clover swards, the acceptability of the grass to sheep necessitates a reduction in grazing pressure in order to maintain sward surface heights. This reduced grazing pressure, while aiding timothy tiller survival, encourages white clover development, results in a positive relationship between tiller number and white clover proportions.

8.5 INDICATIONS FOR FUTURE RESEARCH

Throughout the course of this work the need for further work related to the composition and management of grass / white clover swards was indicated.

* There is a need for strategic work to provide information on the effect of continuous sheep grazing on both medium and small leaved white clovers over a range of different sward surface heights. There may be a place for a blend of small and medium leaved white clovers in this context.

* Work is needed to investigate whether sward surface height guidelines, as prescribed for perennial ryegrass swards, are appropriate to perennial grass / white clover swards or whether different sets of guidelines should apply.

* Guidelines on sward surface heights are needed for non ryegrass swards, both with and without white clover.

* The concept, sometimes advocated, that a mixture of a tetraploid and a diploid perennial ryegrass with white clover is an appropriate compromise between the choice of a diploid or tetraploid companion ryegrass needs to be tested. It is possible that the complementary growth habits of these grasses along with the vigour of the tetraploid provide more competition for the white clover than either grass by itself.

* Work is needed on the possibility of prescribing grass / white clover seeds mixtures for specific management situations e.g. a very early tetraploid perennial ryegrass / white clover mixture may allow earlier lamb production by providing early grass grazing and nutritious white clover rich grazing during finishing.

* The type of strategic work carried out in these experiments needs to be repeated for cattle and sheep + cattle

CHAPTER 9

REFERENCES

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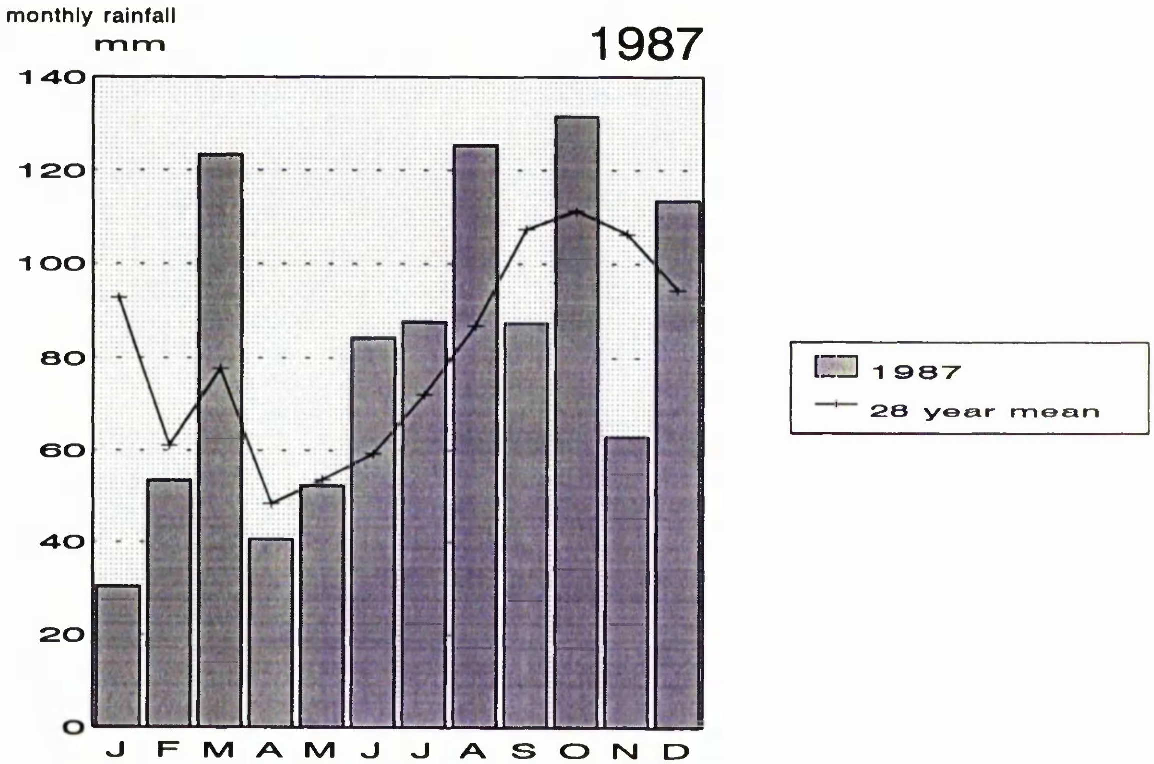
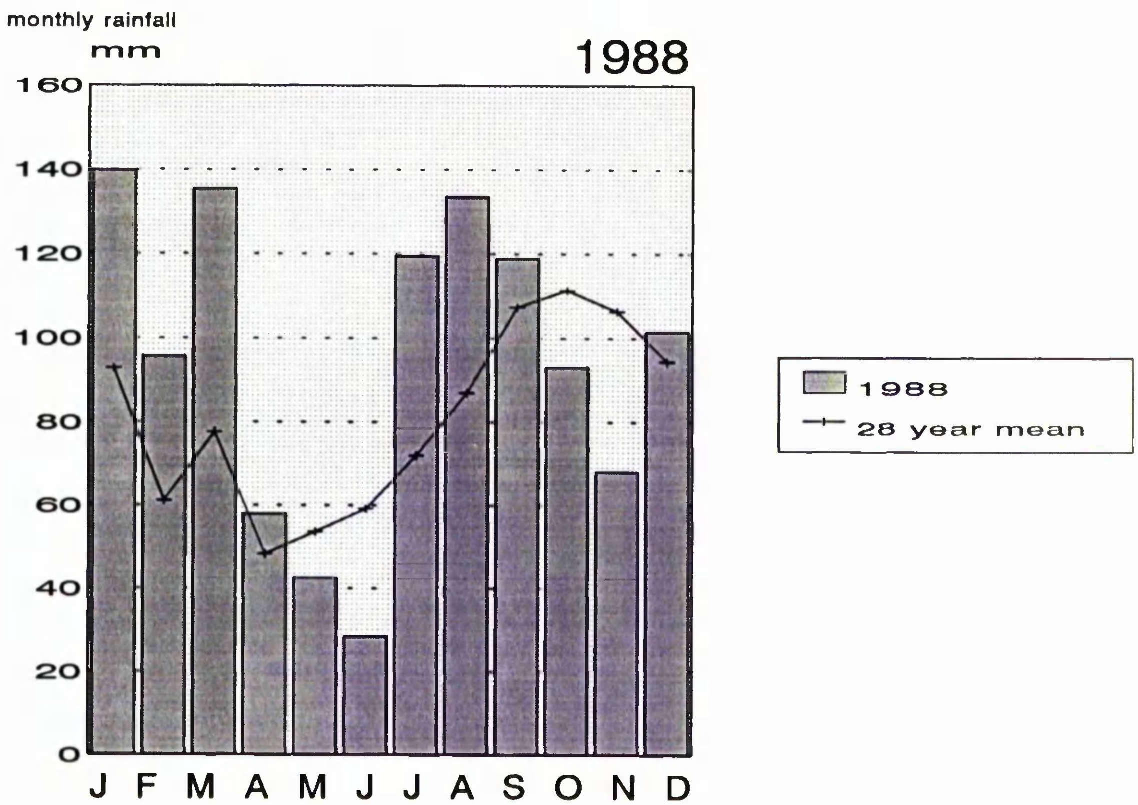
APPENDIX 1

Weather at Auchincruive

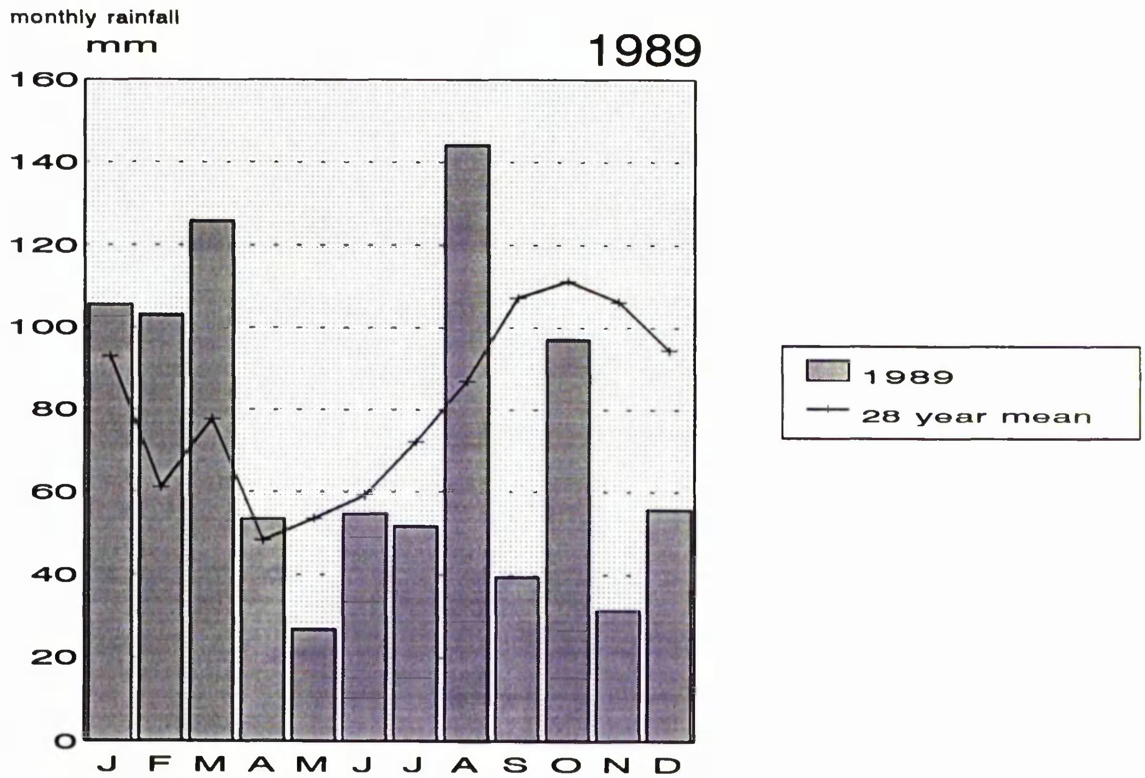
Monthly rainfall at Auchincruive

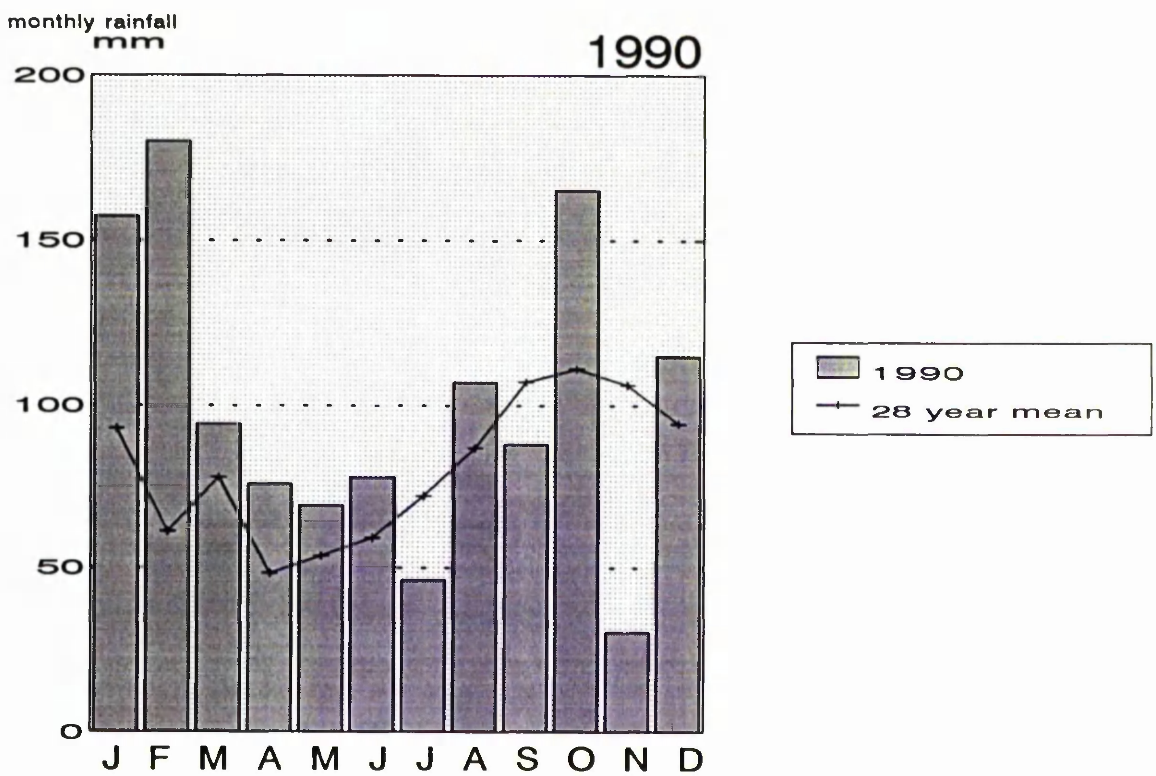
Courtesy of Dr Andrew Walker and Linda Raynor

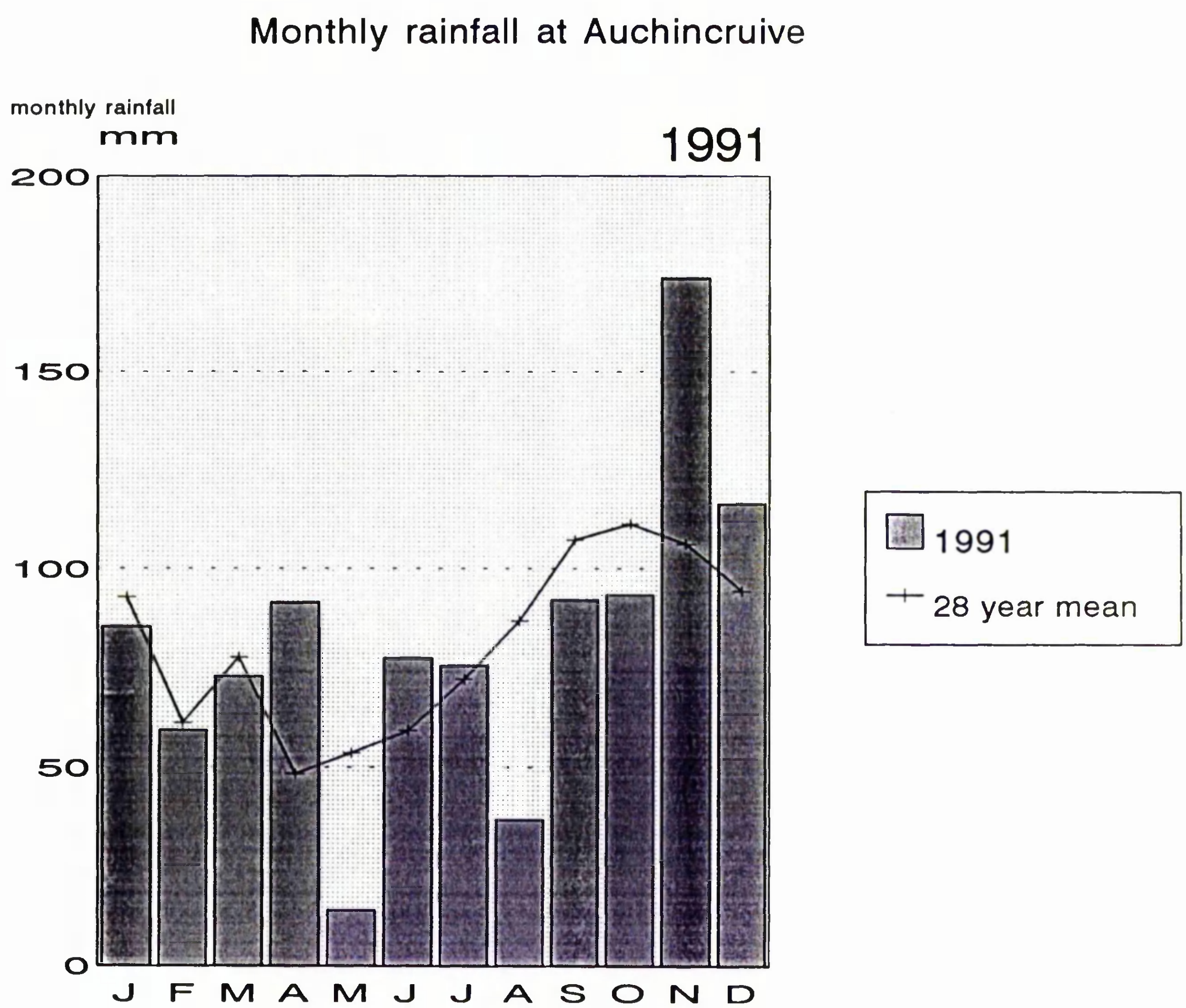




Monthly rainfall at Auchincruive






Monthly rainfall at Auchincruive
monthly rainfall
mm
1991
200
150
100
50
0
J F M A M J J A S O N D
1991
28 year mean

APPENDIX 2

TABLES OF RESULTS

Experiment 1 - Point Quadrat Assessments

The effect of the imposition and timing of a rest, for a conservation cut, on perennial ryegrass / white clover swards, continuously stocked with sheep

Post grazing - October / November of first full grazing year.

Table 11.1 - MEAN NUMBER OF STRIKES PER PLOT (Three ten point quadrats)

Variate	Rest period				SED	F pr.
	None	April-late May	late May & June	July-mid August		
Grass	45.45 (45.79)	40.68 (40.78)	34.45 (35.33)	34.95 (34.85)	7.216 (7.172)	0.441 (0.442)
Clover	12.05 (11.94)	8.89 (8.79)	9.78 (9.42)	11.18 (11.48)	2.029 (2.056)	0.468 (0.414)
Weed	4.49 (4.52)	4.58 (4.63)	7.33 (6.89)	4.83 (4.67)	0.677 (0.756)	0.016 (0.054)
Earth	0.983 (0.99)	1.883 (1.583)	1.7 (1.667)	1.65 (1.208)	0.867 (0.921)	0.75 (0.793)

Table 11.2 - PERCENTAGE OF CANOPY (Three ten point quadrats)

Variate	Rest period				SED	F pr.
	None	April-late May	late May & June	July-mid August		
Grass	72.43 (72.58)	71.97 (72.11)	64.46 (65.97)	66.78 (66.53)	3.663 (3.495)	0.178 (0.209)
Clover	18.28 (18.1)	15.51 (15.3)	17.56 (16.95)	20.47 (20.85)	1.676 (2.11)	0.118 (0.161)
Weed	7.44 (7.42)	8.53 (8.66)	14.33 (13.43)	9.33 (9.04)	2.371 (2.452)	0.1 (0.174)
Earth	1.89 (1.91)	4.03 (4.01)	3.78 (3.75)	3.61 (3.75)	2.142 (2.264)	0.750 (0.778)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

The effect of the imposition and timing of a rest, for a conservation cut, on perennial ryegrass / white clover swards, continuously stocked with sheep.
Post grazing - October / November of first full grazing year.

Table 11.3 - PERCENTAGE COVER BASED ON FIRST STRIKES
Three ten point quadrats (x3.3r)

Variate	Rest period				SED	F pr.
	None	April-late May	late May & June	July-mid August		
Grass	72.14 (72.16)	69.45 (69.42)	62.13 (63.70)	66.36 (65.94)	4.961 (4.828)	0.307 (0.387)
Clover	17.91 (17.86)	15.37 (14.91)	17.91 (17.32)	20.03 (20.41)	1.808 (2.383)	0.186 (0.248)
Weed	6.47 (6.53)	8.67 (9.28)	14.02 (13.09)	7.86 (7.68)	3.121 (3.206)	0.184 (0.286)
Earth	3.37 (3.32)	6.35 (6.25)	5.68 (5.57)	5.60 (5.78)	2.915 (3.121)	0.760 (0.792)

Table 11.4 - CANOPY DENSITY BASED ON TOTAL NUMBER OF STRIKES PER PLOT
Three ten point quadrats

Variate	Rest period				SED	F pr.
	None	April-late May	late May & June	July-mid August		
Strikes	62.98 (63.24)	56.04 (56.05)	53.26 (53.3)	52.66 (52.70)	7.768 (7.648)	0.565 (0.538)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

The effect of ploidy of perennial ryegrass in perennial ryegrass / white clover associations under continuous stocking by sheep.
Post grazing - Oct / Nov of the first full grazing year.

Table 11.5 - MEAN NUMBER OF STRIKES PER PLOT (Three Ten point quadrats)

Variate	Ploidy		SED	F pr.
	Tetraploid	Diploid		
Grass	36.75 (36.14)	41.04 (42.24)	0.731 (0.824)	<0.001 (<0.001)
Clover	10.93 (11.17)	10.02 (9.64)	0.561 (0.615)	0.108 (0.013)
Weed	5.58 (5.49)	5.03 (4.85)	0.452 (0.5)	0.221 (0.201)
Earth	1.73 (1.83)	1.38 (1.28)	0.136 (0.1509)	0.012 (<0.001)

Table 11.6 - PERCENTAGE OF CANOPY (Three Ten point quadrats)

Variate	Ploidy		SED	F pr.
	Tetraploid	Diploid		
Grass	66.74 (66.11)	71.08 (72.48)	0.959 (1.07)	<0.001 (<0.001)
Clover	19.01 (19.54)	16.90 (16.07)	0.928 (1.032)	0.023 (<0.001)
Weed	10.61 (10.48)	9.20 (8.81)	0.817 (0.902)	0.086 (0.065)
Earth	3.75 (4.02)	2.9 (2.69)	0.714 (0.361)	0.008 (<0.001)

Table 11.7 - PERCENTAGE COVER BASED ON FIRST STRIKES
Three Ten point quadrats (x3.3r)

Variate	Ploidy		SED	F pr.
	Tetraploid	Diploid		
Grass	64.84 (64.07)	70.21 (71.54)	1.065 (1.184)	<0.001 (<0.001)
Clover	19.02 (19.36)	16.6 (15.89)	0.994 (1.094)	0.015 (0.002)
Weed	10.17 (10.24)	8.34 (8.05)	0.852 (0.932)	0.033 (0.02)
Earth	5.75 (6.06)	4.75 (4.4)	0.459 (0.508)	0.03 (0.001)

Table 11.8 - CANOPY DENSITY (TOTAL NUMBER OF STRIKES PER PLOT)
Three Ten point quadrats

Variate	Ploidy		SED	F pr.
	Tetraploid	Diploid		
Strikes	54.99 (54.64)	57.47 (58.01)	0.651 (0.728)	<0.001 (<0.001)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

The effect of perennial ryegrass maturity group on perennial ryegrass / white clover associations under continuous stocking by sheep.

Post grazing - October / November of first full grazing year.

Table 11.9 - MEAN NUMBER OF STRIKES PER PLOT (Three ten point quadrats)

Variate	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
Grass	38.16	40.19	37.28	41.14	37.72	1.155	0.002
Clover	10.33	10.37	11.03	9.89	10.76	0.887	0.745
Weed	4.96	5.10	5.71	4.93	5.83	0.715	0.572
Earth	1.677	1.573	1.875	1.083	1.563	0.215	0.006

Table 11.10 - PERCENTAGE OF CANOPY (Three ten point quadrats)

Variate	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
Grass	68.96	70.03	66.04	72.17	67.34	1.516	<1.001
Clover	18.28	17.06	19.29	16.57	18.56	1.467	0.331
Weed	9.28	9.58	10.7	9.03	10.95	1.292	0.469
Earth	3.63	3.42	4.09	2.28	3.22	0.505	0.008

The effect of perennial ryegrass maturity group on perennial ryegrass / white clover associations under continuous stocking by sheep.

Post grazing - October / November of first full grazing year.

Table 11.11 - PERCENTAGE COVER BASED ON FIRST STRIKES

Three ten point quadrats (x3.3r)

Variate	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
Grass	68.15	68.47	63.76	70.83	66.40	1.684	<0.001
Clover	17.46	17.28	19.36	16.4	18.53	1.571	0.365
Weed	8.51	8.95	10.47	8.66	9.69	1.347	0.568
Earth	5.66	5.26	6.23	3.78	5.32	0.726	0.15

Table 11.12 - CANOPY DENSITY BASED ON TOTAL NUMBER OF STRIKES / PLOT

Three ten point quadrats

Variate	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
Strikes	55.12	57.24	55.9	57.03	55.87	1.03	0.211

The effect of clover leaf size on perennial ryegrass / white clover associations under continuous stocking by sheep.

Post grazing - October / November of the first full grazing year.

Table 11.13 - MEAN NUMBER OF STRIKES PER PLOT (Three ten point quadrats)

Variate	Clover leaf size				SED	F pr.
	VL	L	M	S		
Grass	42.17 (42.25)	39.32 (39.68)	40.3 (41.02)	33.78 (33.81)	1.033 (1.165)	<0.001 (<0.001)
Clover	3.7 (3.88)	8.05 (7.95)	7.72 (7.55)	22.43 (22.25)	0.794 (0.869)	<0.001 (<0.001)
Weed	5.75 (5.92)	5.22 (5.19)	5.92 (5.16)	4.33 (4.44)	0.639 (0.707)	0.061 (0.225)
Earth	1.742 (1.75)	1.617 (1.583)	1.7 (1.667)	1.158 (1.208)	0.1923 (0.2134)	0.009 (0.059)

Table 11.14 - PERCENTAGE OF CANOPY (Three ten point quadrats)

Variate	Clover leaf size				SED	F pr.
	VL	L	M	S		
Grass	77.9 (77.33)	71.7 (72.08)	71.32 (72.93)	54.83 (54.85)	1.356 (1.514)	<0.001 (<0.001)
Clover	7.28 (7.53)	14.96 (14.7)	14.08 (13.83)	35.59 (35.15)	1.312 (1.459)	<0.001 (<0.001)
Weed	11.23 (11.44)	9.82 (5.19)	11.17 (9.83)	7.43 (7.6)	1.155 (1.276)	0.003 (0.029)
Earth	3.81 (3.83)	3.58 (3.54)	3.57 (3.56)	2.35 (2.48)	0.452 (0510)	0.006 (0.043)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

The effect of clover leaf size on perennial ryegrass / white clover associations under continuous stocking by sheep.
Post grazing - October / November of the first full grazing year.

Table 11.15 - PERCENTAGE COVER BASED ON FIRST STRIKES - Three ten point quadrats (x3.33r)

Variate	Clover leaf size				SED	F pr.
	VL	L	M	S		
Grass	75.49 (74.91)	69.23 (69.35)	70.28 (71.88)	55.09 (55.07)	1.506 (1.674)	<0.001 (<0.001)
Clover	7.79 (8.11)	15.45 (15.32)	13.92 (13.52)	34.07 (33.54)	1.405 (1.547)	<0.001 (<0.001)
Weed	10.7 (10.87)	9.63 (9.78)	9.82 (8.72)	6.87 (7.21)	1.205 (1.318)	0.011 (0.04)
Earth	5.93 (5.98)	5.58 (5.43)	5.69 (5.55)	3.8 (3.97)	0.64 (0.718)	0.004 (0.032)

Table 11.16 - CANOPY DENSITY BASED ON TOTAL NUMBER OF STRIKES / PLOT
(Three ten point quadrats)

Variate	Clover leaf size				SED	F pr.
	VL	L	M	S		
Strikes	53.37 (53.79)	54.22 (54.4)	55.64 (55.4)	61.7 (61.71)	0.921 (1.029)	<0.001 (<0.001)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

The interaction of perennial ryegrass ploidy and maturity group on perennial ryegrass / white clover swards under continuous stocking by sheep.

Post grazing - October / November of first full grazing year.

Table 11.17 - MEAN NUMBER OF STRIKES PER PLOT (Three ten point quadrats)

Variate	PRG	Perennial ryegrass maturity group					SED	F pr.
		VE	E	I	L	VL		
Grass	Tet	34.35	37.19	32.73	40.29	39.21	1.634	<0.001
	Dip	41.96	43.06	41.83	41.98	36.23		
Clover	Tet	10.50	11.75	12.46	10.44	9.96	1.255	0.095
	Dip	10.17	9.21	9.6	9.58	12.87		
Weed	Tet	5.46	5.00	6.35	4.85	5.94	1.01	0.864
	Dip	4.46	5.15	5.12	4.75	5.73		
Earth	Tet	2.125	1.854	2.188	1.125	1.313	0.304	0.01
	Dip	1.229	1.292	1.542	1.042	1.813		

Table 11.18 - PERCENTAGE OF CANOPY (Three ten point quadrats)

Variate	PRG	Perennial ryegrass maturity group					SED	F pr.
		VE	E	I	L	VL		
Grass	Tet	65.48	66.88	60.65	71.46	69.23	2.144	<0.001
	Dip	72.44	73.19	71.44	72.87	65.46		
Clover	Tet	19.54	19.60	22.25	16.75	16.92	2.075	0.013
	Dip	17.02	14.52	16.33	16.40	20.21		
Weed	Tet	10.56	9.56	12.31	9.5	11.12	1.827	0.659
	Dip	8.0	9.6	9.08	8.56	10.77		
Earth	Tet	4.67	4.10	4.96	2.33	2.71	0.714	0.012
	Dip	2.58	2.73	3.23	2.23	3.73		

The interaction of perennial ryegrass ploidy and maturity group on perennial ryegrass / white clover swards under continuous stocking by sheep.

Post grazing - October / November of first full grazing year.

Table 11.19 - PERCENTAGE COVER BASED ON FIRST STRIKES
Three ten point quadrats (x3.3r)

Variate	PRG	Perennial ryegrass maturity group					SED	F pr.
		VE	E	I	L	VL		
Grass	Tet	64.08	64.77	58.37	69.04	67.94	2.382	<0.001
	Dip	72.21	72.17	69.15	72.63	64.85		
Clover	Tet	18.56	19.42	22.13	17.33	17.65	2.222	0.183
	Dip	16.35	15.15	16.6	15.46	19.42		
Weed	Tet	10.19	9.67	11.92	9.19	9.87	1.905	0.783
	Dip	6.83	8.23	9.02	8.12	9.5		
Earth	Tet	7.04	6.1	7.38	3.73	4.5	1.026	0.013
	Dip	4.27	4.42	5.08	3.83	6.15		

Table 11.20 - CANOPY DENSITY (TOTAL NUMBER OF STRIKES / PLOT)
(Three ten point quadrats)

Variate	PRG	Perennial ryegrass maturity group					SED	F pr.
		VE	E	I	L	VL		
Strikes	Tet	52.44	55.65	53.75	56.71	56.42	1.457	0.011
	Dip	57.81	58.83	58.04	57.35	55.35		

APPENDIX 3

TABLES OF RESULTS

Experiment 1 - Grid Quadrat Assessments
INTERACTIONS

Table 12.1 - The interaction of perennial ryegrass maturity group and the imposition and timing of a rest for a conservation cut, on the presence of clover in perennial ryegrass / white clover swards,continuously stocked with sheep.

$0.64m^2$ quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Rest period	Perennial ryegrass maturity group					SED () at same level of graze	F pr.
	VE	E	I	L	VL		
October / November Post grazing assessment after first full grazing year after establishment year.							
No rest	74.1	70.0	75.9	73.8	77.5	12.283 (4.721)	0.150
April-late May	75.3	71.0	71.9	67.8	77.3		
late May & June	72.7	70.0	74.7	63.5	67.1		
July-mid August	76.5	75.6	67.5	77.9	71.5		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.							
No rest	71.1	56.0	53.2	40.2	52.3	8.59 (7.36)	0.616
April-late May	48.9	48.9	45.2	38.1	51.9		
late May & June	56.5	47.1	51.4	41.7	42.2		
July-mid August	54.7	43.3	48.1	45.9	45.3		
October / November Post grazing assessment after the second grazing year after the establishment year.							
No rest	48.3	46.1	49.5	48.1	48.5	9.68 (6.71)	0.859
April-late May	36.1	36.4	30.0	28.7	32.5		
late May & June	53.8	50.2	49.7	45.0	42.2		
July-mid August	78.0	71.1	65.1	59.3	63.0		

Table 12.2 - The interaction of perennial ryegrass ploidy and the imposition and timing of a rest for a conservation cut, on the presence of clover in perennial ryegrass / white clover swards, continuously stocked with sheep.

$0.64m^2$ quadrats: Number of 8cm x 8cm squares in which clover was present - out of 100

Rest period	Perennial ryegrass ploidy		SED * for same levels of graze	F pr.
	Tetraploid	Diploid		
October / November Post grazing assessment after first full grazing year after establishment year.				
No rest	74.2 (74.6)	73.1 (72.3)	11.726 (11.708)	0.664 (0.195)
April-late May	75.8 (77.0)	69.5 (66.0)	*2.986 (3.326)	
late May & June	71.2 (71.6)	68.0 (68.9)		
July-mid August	75.4 (76.0)	72.3 (72.7)		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.				
No rest	56.0 (57.0)	53.1 (53.2)	6.42 (7.07)	0.59 (0.585)
April-late May	52.2 (51.8)	41.0 (38.8)	*4.65 (5.24)	
late May & June	50.8 (52.4)	44.8 (46.0)		
July-mid August	50.4 (51.5)	46.0 (47.0)		
October / November Post grazing assessment after the second grazing year after the establishment year.				
No rest	51.9 (51.2)	44.3 (44.8)	8.16 (8.56)	0.521 (0.403)
April-late May	38.9 (38.8)	26.6 (26.8)	*4.25 (4.76)	
late May & June	53.6 (54.9)	42.8 (44.5)		
July-mid August	69.3 (61.9)	65.3 (67.6)		

Values in brackets() are for re-analysis with both very late perennial ryegrass associations omitted.

Table 12.3 - The interaction of perennial ryegrass ploidy and clover leaf size, on the presence of clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

0.64m^2 quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Perennial ryegrass ploidy	White clover leaf size				SED	F pr.
	VL	L	M	S		
October / November Post grazing assessment after first full grazing year after establishment year.						
Tetraploid	49.8 (50.5)	69.5 (69.3)	80.3 (82.7)	97.0 (96.7)	2.986 (3.324)	0.099 (0.071)
Diploid	41.9 (40.4)	71.9 (70.2)	75.3 (74.7)	93.8 (94.5)		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.						
Tetraploid	16.5 (16.7)	49.3 (49.7)	46.1 (49.2)	97.5 (97.1)	4.65 (5.24)	0.614 (0.366)
Diploid	13.5 (13.6)	43.6 (43.5)	35.0 (34.5)	93.5 (93.5)		
October / November Post grazing assessment after the second grazing year after the establishment year.						
Tetraploid	20.9 (21.9)	54.1 (53.6)	41.1 (41.6)	97.4 (97.0)	4.25 (4.76)	0.001 (0.07)
Diploid	20.9 (20.7)	34.4 (35.5)	32.2 (34.6)	91.5 (92.8)		

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

Table 12.4 - The interaction of perennial ryegrass ploidy and perennial ryegrass maturity group, on the presence of clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

0.64m^2 quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Perennial ryegrass ploidy	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
October / November Post grazing assessment after first full grazing year after establishment year.							
Tetraploid	76.6	73.0	76.6	73.0	71.5	3.339	0.281
Diploid	72.7	70.4	68.4	68.5	73.7		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.							
Tetraploid	64.0	56.6	55.9	41.1	49.0	5.2	0.217
Diploid	51.6	48.6	43.0	41.8	46.9		
October / November Post grazing assessment after the second grazing year after the establishment year.							
Tetraploid	57.9	54.2	55.2	46.7	53.0	4.75	0.484
Diploid	50.2	47.7	42.0	43.9	40.1		

Table 12.5 - The interaction of clover leaf size and perennial ryegrass maturity group, on the presence of clover in perennial ryegrass / white clover swards, continuously stocked with sheep.

$0.64m^2$ quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

White clover leaf size	Perennial ryegrass maturity group					SED	F pr.
	VE	E	I	L	VL		
October / November Post grazing assessment after first full grazing year after establishment year.							
Very large	43.38	44.46	48.33	45.67	47.21		
Large	73.58	69.63	73.79	62.04	74.46		
Medium	82.79	77.75	76.04	78.25	74.21	4.721	0.282
Small	98.88	94.83	91.79	97.00	94.5		
March / April Pre-grazing assessment prior to the second grazing year after establishment year.							
Very large	16.8	18.8	15.1	9.8	14.4		
Large	59.4	42.0	53.5	31.5	45.8		
Medium	57.6	43.6	32.5	33.5	35.4	7.36	0.206
Small	97.5	96.0	96.8	90.8	96.2		
October / November Post grazing assessment after the second grazing year after the establishment year.							
Very large	20.0	27.3	20.5	17.3	19.5		
Large	55.8	39.0	48.0	35.5	43.2		
Medium	40.7	40.0	33.5	38.2	30.9	6.71	0.53
Small	99.6	97.5	92.4	91.1	92.7		

Table 12.6 The interactions of clover leaf size, perennial ryegrass maturity group and the imposition of a rest for a conservation cut, on the presence of white clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

October / November post grazing assessment after the second grazing year after the establishment year.

0.64m² quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Rest period	Clover leaf size	Perennial ryegrass maturity group				
		VE	E	I	L	VL
No rest	Very large	18.3	20.5	27.2	14.7	22.5
	Large	48.7	25.5	53.3	32.3	45.5
	Medium	27.7	38.7	24.5	53.8	27.7
	Small	98.7	99.7	93.0	91.5	98.5
April- late May	Very large	11.7	11.2	3.8	5.8	8.8
	Large	10.3	17.5	29.3	18.5	20.8
	Medium	22.3	20.8	10.3	19.2	20.3
	Small	100.0	96.2	76.7	71.3	79.8
late May & June	Very large	12.0	8.8	16.2	22.8	8.7
	Large	73.0	46.7	44.7	22.3	40.2
	Medium	30.3	45.3	38.2	35.5	20.7
	Small	100.0	100.0	100.0	99.3	99.5
July-mid August	Very large	38.2	68.7	35.0	26.0	37.8
	Large	91.2	66.2	64.5	68.8	66.2
	Medium	82.7	55.3	61.0	44.2	54.8
	Small	99.8	94.2	100.0	98.2	93.0

SED	F pr.
15.13 (15.24)	0.168 (0.039)
*13.43 (13.47)	

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.
* At the same levels of rest; rest.clover; rest maturity.

Table 12.7 - The interactions of perennial ryegrass ploidy, clover leaf size and the imposition and timing of a rest for a conservation cut, on the presence of white clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

October / November post grazing assessment after the second grazing year after the establishment year.

0.64m^2 quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Rest period	Perennial ryegrass ploidy	White clover leaf size			
		Very large	Large	Medium	Small
No rest	Tetraploid	20.5 (20.5)	49.5 (44.5)	38.1 (40.1)	99.5 (99.7)
	Diploid	20.7 (19.8)	32.7 (35.4)	30.9 (32.2)	93.0 (91.8)
April-late May	Tetraploid	9.2 (8.8)	29.1 (30.3)	27.1 (27.8)	90.1 (88.3)
	Diploid	7.3 (7.4)	9.5 (7.5)	10.1 (8.6)	79.5 (83.7)
Late May & June	Tetraploid	15.9 (17.9)	62.9 (64.3)	35.5 (37.5)	100.0 (100.0)
	Diploid	11.5 (12.0)	27.9 (29.0)	32.5 (37.2)	99.5 (99.7)
July-mid August	Tetraploid	38.9 (40.3)	75.1 (75.1)	63.8 (61.0)	100.0 (100.0)
	Diploid	44.1 (43.6)	67.7 (70.3)	55.4 (60.6)	94.1 (96.1)

SED	F pr.
10.99 (11.89)	0.721 (0.657)
* 8.49 (9.53)	

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.
* At the same levels of rest; rest.clover; rest.ploidy.

Table 12.8 -The interactions of perennial ryegrass ploidy, perennial ryegrass maturity group and clover leaf size, on the presence of white clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

October / November post grazing assessment after the second grazing year after the establishment year.

0.64m^2 quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Clover leaf size	Perennial ryegrass ploidy	Perennial ryegrass maturity group				
		VE	E	I	L	VL
Very large	Tetraploid	20.3	31.0	20.4	15.8	17.2
	Diploid	19.7	23.6	20.7	18.8	21.7
Large	Tetraploid	62.2	47.2	64.5	40.3	56.3
	Diploid	49.4	30.7	31.4	30.7	30.0
Medium	Tetraploid	49.0	40.2	39.6	37.6	39.3
	Diploid	32.5	39.9	27.4	38.7	22.4
Small	Tetraploid	100.0	98.5	96.5	93.0	99.0
	Diploid	99.3	96.5	88.3	87.2	86.4

SED	F pr.
9.49 (9.53)	0.906 (0.86)

Values in brackets () are for re-analysis with both very late perennial ryegrass associations omitted.

Table 12.9 - The interactions of perennial ryegrass ploidy, perennial ryegrass maturity group and imposition of a rest period, on the presence of white clover in perennial ryegrass / white clover associations, continuously stocked with sheep.

October / November post grazing assessment after the second grazing year after the establishment year.

$0.64m^2$ quadrats: Number of 80 mm x 80 mm squares in which clover was present - out of 100

Rest period	Perennial ryegrass ploidy	Perennial ryegrass maturity group				
		VE	E	I	L	VL
None	Tetraploid	49.7	48.7	52.6	53.7	54.7
	Diploid	46.9	43.4	46.4	42.5	42.3
April - late May	Tetraploid	41.2	39.4	40.1	34.6	39.1
	Diploid	31.0	33.4	20.0	22.8	25.8
Late May & June	Tetraploid	57.7	55.4	59.9	46.7	48.2
	Diploid	49.9	45.0	39.6	43.3	36.3
July - mid August	Tetraploid	82.8	73.3	68.4	51.8	69.8
	Diploid	73.1	68.8	61.8	66.8	56.1

SED	F pr.
11.78 (9.49)	0.931

SED values in brackets () are for the same levels of rest; rest.ploidy; rest.maturity.

APPENDIX 4

Tables of Results

Canopy Architecture - Experiment 1

Table 13.1 - The influence of conservation cut management and white clover leaf size on perennial ryegrass tiller number and height and on the morphology of white clover in perennial ryegrass / white clover associations. (just prior to first cut - mid May)

White clover parameter	White clover leaf size				SED	F pr.
	Very large	Large	Medium	Small		
Grass height (mm)	430	408	391	422	1.776	0.131
White clover height (mm)	251	239	230	228	1.019	0.088
Growth points (No. / m^2)	284	228	425	600	51.2	<0.001
Grass tillers (No. / m^2)	3296	3553	3022	2981	157.4	0.001
Trifoliate leaves (No. / m^2)	1036	777	1498	2377	165.7	<0.001
Folded lamina (length [mm] x 2)	205.9	194.4	168.2	119.5	22.57	0.001
1st lamina (length x breadth [mm])	333.2	275.4	237.3	192.8	27.73	<0.001
2nd lamina (length x breadth [mm])	205.7	182.1	131.1	126.1	18.3	<0.001
3rd lamina (length x breadth [mm])	128.8	99.8	84.8	77.7	16.3	0.018
Folded lamina petiole length (mm)	30.8	27.4	22.6	28.3	3.8	0.183
1st petiole length (mm)	100.2	99.4	82.9	82.4	7.96	0.032
2nd petiole length (mm)	86.5	84.7	68.3	73.1	6.61	0.017
3rd petiole length (mm)	70.8	61.2	52.9	51.8	8.0	0.077

Table 13.2 - The influence of conservation cut management and white clover leaf size on perennial ryegrass height and on the morphology of white clover in perennial ryegrass / white clover associations.(just prior to third cut - early August)

White clover parameter	White clover leaf size				SED	F pr.
	Very large	Large	Medium	Small		
Grass height (mm)	315	322	281	318	24.74	0.333
Clover height (mm)	124	127	114	118	12.49	0.717
Folded lamina (length [mm] x 2)	244	211	180	153	49.6	0.307
1st lamina (length x breadth [mm])	425	364	356	247	62.7	0.054
2nd lamina (length x breadth [mm])	479	419	329	261	58.6	0.006
3rd lamina (length x breadth [mm])	549	336	320	250	35.1	<0.001
4th lamina (length x breadth [mm])	563	266	341	166		
5th lamina (length x breadth [mm])	361	240	363	83		
Folded lamina petiole length (mm)	24.8	25.5	20.0	24.7	4.13	0.529
1st petiole length (mm)	63.6	58.8	57.4	48.2	7.41	0.227
2nd petiole length (mm)	99.2	84.0	74.0	71.4	8.55	0.015
3rd petiole length (mm)	121.5	106.7	90.2	91.0	6.19	0.002
4th petiole length (mm)	136.1	88.2	119.3	85.0		
5th petiole length (mm)	104.2	78.5	102.6	80.0		

Table 13.3 - The influence of continuous stocking by sheep and white clover leaf size on the morphology of white clover in perennial ryegrass / white clover associations. (July)

White clover parameter	White clover leaf size				SED	F pr.
	Very large	Large	Medium	Small		
Growth points (No. / m^2)	73	109	109	274	25.42	<0.001
Folded lamina (length [mm] x 2)	104.1	109.6	92.3	71.2	12.18	0.011
1st lamina (length x breadth [mm])	159.2	154.5	172.3	106.8	16.39	<0.001
2nd lamina (length x breadth [mm])	264.3	219.1	197.3	107.4	12.17	<0.001
3rd lamina (length x breadth [mm])	127.3	127.0	228.1	98.85	10.69	<0.001
4th lamina (length x breadth [mm])	156.7	111.0	85.9	108.7		
Folded lamina petiole length (mm)	14.37	17.73	15.81	13.38	2.099	0.19
1st petiole length (mm)	39.5	41.1	43.7	34.5	4.34	0.198
2nd petiole length (mm)	81.6	78.3	64.9	45.8	5.64	<0.001
3rd petiole length (mm)	25.5	47.8	86.0	53.0	9.491	<0.001
4th petiole length (mm)	42.7	38.4	61.9	49.67		

Table 13.4 - The influence of conservation cut management and perennial ryegrass ploidy on perennial ryegrass tiller number and height and on the morphology of white clover in perennial ryegrass / white clover associations.
(just prior to first cut - mid May)

White clover parameter	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
Grass height (mm)	393	432	1.256	0.003
White clover height (mm)	223	251	0.72	<0.001
Growth points (No. / m^2)	407	361	3.62	0.206
Grass tillers (No. / m^2)	2997	3429	111.3	<0.001
Trifoliate leaves (No. / m^2)	1529	1314	117.2	0.071
Folded lamina (length [mm] x 2)	169.8	174.2	15.96	0.786
1st lamina (length x breadth [mm])	239.5	279.8	19.16	0.043
2nd lamina (length x breadth [mm])	144.4	178.1	12.94	0.011
3rd lamina (length x breadth [mm])	78.2	117.3	11.69	0.002
Folded lamina petiole length (mm)	27.0	27.6	2.69	0.817
1st petiole length (mm)	81.5	101.0	5.63	<0.001
2nd petiole length (mm)	70.3	86.0	6.61	0.001
3rd petiole length (mm)	47.2	71.2	8.00	<0.001

Table 13.5 - **The influence of conservation cut management and perennial ryegrass ploidy on perennial ryegrass height and on the morphology of white clover in perennial ryegrass / white clover associations.** (just prior to third cut - early August)

White clover parameter	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
Grass height (mm)	284	335	17.49	0.006
Clover height (mm)	118	123	8.83	0.565
Folded lamina (length [mm] x 2)	207	187	35.1	0.579
1st lamina (length x breadth [mm])	350	346	44.3	0.923
2nd lamina (length x breadth [mm])	336	408	41.4	0.098
3rd lamina (length x breadth [mm])	347	380	24.8	0.223
4th lamina (length x breadth [mm])	294	374		
5th lamina (length x breadth [mm])	214	309		
Folded lamina petiole length (mm)	25.6	22.0	2.92	0.228
1st petiole length (mm)	55.2	58.8	5.24	0.502
2nd petiole length (mm)	76.8	87.4	6.05	0.093
3rd petiole length (mm)	99.8	104.9	4.38	0.276
4th petiole length (mm)	98.8	115.6		
5th petiole length (mm)	77.3	105.3		

Table 13.6 - The influence of continuous stocking by sheep and perennial ryegrass ploidy on the morphology of white clover in perennial ryegrass / white clover associations. (July)

White clover parameter	Perennial ryegrass ploidy		SED	F pr.
	Tetraploid	Diploid		
Growth points (No. / m^2)	155	128	17.98	0.14
Folded lamina (length [mm] x 2)	83.4	105.2	8.61	0.013
1st lamina (length x breadth [mm])	137.4	159.0	11.59	0.066
2nd lamina (length x breadth [mm])	228.1	166.0	8.61	<0.001
3rd lamina (length x breadth [mm])	134.8	155.8	7.56	0.018
4th lamina (length x breadth [mm])	127.3	103.9		
Folded lamina petiole length (mm)	14.18	16.46	1.484	0.128
1st petiole length (mm)	32.6	46.7	3.07	<0.001
2nd petiole length (mm)	72.3	63.0	3.98	0.028
3rd petiole length (mm)	43.9	62.3	6.711	0.019
4th petiole length (mm)	58.91	37.36		

Table 13.7 - The influence of conservation cut management and perennial ryegrass maturity group on perennial ryegrass tiller number and height and on the morphology of white clover in perennial ryegrass / white clover associations. (just prior to first cut - mid May)

White clover parameter	Perennial ryegrass maturity group					SED	F pr.
	Very early	Early	Intermediate	Late	Very late		
Grass height (mm)	521	533	421	316	272	1.986	<0.001
White clover height (mm)	251	252	256	222	204	1.139	<0.001
Growth points (No. / m^2)	438	382	332	317	451	57.3	0.073
Grass tillers (No. / m^2)	2765	2710	3149	3946	3496	176	<0.001
Trifoliate leaves (No. / m^2)	1504	1544	1108	1242	1710	185.3	0.012
Folded lamina (length [mm] x 2)	174.5	200.6	169.6	147.1	168.2	25.24	0.34
1st lamina (length x breadth [mm])	271.3	289.4	257.6	243.7	236.4	31	0.442
2nd lamina (length x breadth [mm])	164.4	164.4	167.4	150.0	160.1	20.46	0.925
3rd lamina (length x breadth [mm])	100.8	84.8	82.1	114.7	106.4	18.49	0.35
Folded lamina petiole length (mm)	27.0	33.3	27.2	24.2	24.7	4.25	0.221
1st petiole length (mm)	95.5	109.2	99.2	84.5	67.8	8.9	<0.001
2nd petiole length (mm)	83.3	88.7	75.1	75.2	68.6	7.39	0.071
3rd petiole length (mm)	63.4	60.3	64.0	55.1	53.0	8.94	0.66

Table 13.8 - The influence of conservation cut management and perennial ryegrass maturity group on perennial ryegrass height and on the morphology of white clover in perennial ryegrass / white clover associations. (just prior to third cut - early August)

White clover parameter	Perennial ryegrass maturity group					SED	F pr.
	Very early	Early	Intermediate	Late	Very late		
Grass height (mm)	357	306	315	304	263	27.66	0.034
Clover height (mm)	121	115	121	119	128	13.96	0.565
Folded lamina (length [mm] x 2)	205	198	217	171	195	55.5	0.944
1st lamina (length x breadth [mm])	369	350	336	315	369	70.1	0.928
2nd lamina (length x breadth [mm])	371	344	356	401	388	65.5	0.905
3rd lamina (length x breadth [mm])	352	268	354	381	463	39.3	0.01
4th lamina (length x breadth [mm])	388	269	347	343	322		
5th lamina (length x breadth [mm])	234	279	167	331	298		
Folded lamina petiole length (mm)	25.6	22.3	30.0	19.3	21.7	4.62	0.196
1st petiole length (mm)	53.9	60.0	57.0	55.1	58.9	8.29	0.942
2nd petiole length (mm)	77.2	82.2	84.7	85.8	80.8	9.56	0.906
3rd petiole length (mm)	97.3	91.5	110.5	103.8	108.5	6.92	0.107
4th petiole length (mm)	92.9	93.2	128.3	110.7	110.7		
5th petiole length (mm)	81.4	94.5	83.4	100.2	97.1		

APPENDIX 5

Tables of Results

EXCLOSURE CAGE DATA - Experiment 2

Table 14.1 - Effect of companion grass species (ploidy), and time of year on herbage production under grazing in grass / white clover swards under continuous stocking with sheep (kg herbage dry matter / ha at 21 day {approximately} intervals).

White clover companion grass type	1990								
	18 April	9 May	31 May	20 Jun	13 Jul	8 Aug	5 Sep	23 Nov	Annual Total
Perennial ryegrass (T)	1709	2530	1168	1000	1707	1110	1623	2399	13043
Perennial ryegrass (D)	1047	2278	1126	1692	1891	1005	2420	2261	13410
Meadow fescue	1373	1835	1797	2191	2370	1773	1543	1160	13688
Cocksfoot	1030	1988	2130	1605	2752	1776	2725	2132	14272
Timothy	461	2002	1897	2249	1806	1988	1801	1097	12841
SED	268.1	548.6	337.7	572.7	363.5	260.6	536.3	477.6	533.1
F pr.	0.016	0.732	0.059	0.271	0.089	0.018	0.205	0.063	0.155

Table 14.2 - Effect of companion grass species (ploidy), and time of year on herbage production under grazing in grass / white clover swards under continuous stocking with sheep (kg herbage dry matter / ha at 21 day {approximately} intervals).

White clover companion grass type	1991							
	9 May	4 June	27 June	18 July	8 August	12 September	21 October	Annual Total
Perennial ryegrass (T)	2811	2603	827	1582	1023	1975	1134	12213
Perennial ryegrass (D)	2757	2421	850	1505	1059	1613	775	11137
Meadow fescue	2820	2202	1175	1924	1753	1798	984	12468
Cocksfoot	2109	1986	1326	1882	1191	2231	672	11382
Timothy	2852	2187	1073	1802	1661	1061	445	11278
SED	181.5	513.3	622.7	231.6	461.7	505.5	449	689.9
F pr.	0.015	0.786	0.911	0.351	0.413	0.284	0.604	0.284

Table 14.3 - Herbage growth rate (kg dry matter / hectare / day) from grass / white clover swards under continuous stocking with sheep.

White clover companion grass type	1990 (day number / month number)							
	1/4 - 18/4	18/4 -9/5	9/5 - 31/5	31/5 - 20/6	20/6 - 13/7	13/7 - 8/8	8/8 - 5/9	5/9 - 23/11
Perennial ryegrass (T)	94.9	120.5	53.1	50.6	74.2	50.5	60.1	50.0
Perennial ryegrass (D)	58.2	108.5	51.2	84.6	82.3	45.7	89.6	47.1
Meadow fescue	76.3	87.4	81.7	109.5	103.0	80.6	57.1	24.2
Cocksfoot	57.2	94.7	96.8	80.3	119.7	80.7	100.9	44.4
Timothy	25.6	95.3	86.2	112.5	78.5	90.4	66.7	22.9
SED	14.89	26.13	15.36	28647	15.80	11.84	19.87	9.956
F pr.	0.016	0.732	0.059	0.271	0.089	0.018	0.205	0.063

Table 14.4 - Herbage growth rate (kg dry matter / hectare / day) in grass / white clover swards under continuous stocking with sheep.

White clover companion grass type	1991 (day number / month number)						
	1/4 - 9/5	9/5 - 4/6	4/6 - 27/6	27/6 - 18/7	18/7 - 8/8	8/8 - 12/9	12/9 - 21/10
Perennial ryegrass (T)	72.1	100.1	36.0	75.3	48.7	56.4	29.1
Perennial ryegrass (D)	70.7	93.1	36.9	71.7	50.4	46.1	19.9
Meadow fescue	72.3	84.7	51.1	91.6	83.5	51.4	25.2
Cocksfoot	54.1	76.4	57.7	89.6	56.7	63.8	17.2
Timothy	73.1	84.1	46.6	85.8	79.1	30.3	11.4
SED	4.66	19.74	27.07	11.02	21.99	14.44	11.51
F pr.	0.015	0.786	0.911	0.351	0.413	0.284	0.605

Table 14.5 - Effect of companion grass species (ploidy), and time of year on the white clover content of grass / white clover swards under continuous stocking with sheep (white clover dry matter as a percentage of total herbage dry matter).

White clover companion grass type	1990								
	18 April		9 May		31 May		8 August		23 November
	Cage	Graze	Cage	Graze	Cage	Graze	Cage	Graze	Cage
Perennial ryegrass (T)	4.13	1.63	6.1	1.1	11.8	4.5	28.8	8.3	8.5
Perennial ryegrass (D)	4.17	2.77	12.2	2.7	20.0	10.9	25.1	2.7	10.3
Meadow fescue	7.53	2.93	17.6	7.0	32.7	15.6	27.7	15.5	13.9
Cocksfoot	8.2	3.33	16.7	13.0	39.7	18.1	12.1	6.9	3.9
Timothy	6.33	3.53	23.9	19.5	39.1	28.4	36.6	29.2	18.3
SED	2.565	1.241	3.91	8.75	8.52	6.37	12.98	11.55	6.27
F pr.	0.43	0.606	0.018	0.286	0.041	0.048	0.487	0.257	0.286
Grand mean	6.07	2.84	15.3	8.7	28.7	15.5	26.1	12.5	11.0

Table 14.6 - Effect of companion grass species (ploidy), and time of year on the white clover content of grass / white clover swards under continuous stocking with sheep (white clover dry matter as a percentage of total herbage dry matter).

White clover companion grass type	1991										
	9 May		4 June		27 June		8 August		12 September		21 October
	Cage	Graze	Cage	Graze	Cage	Graze	Cage	Graze	Cage	Graze	Cage
Perennial ryegrass (T)	11.5	12.4	15.8	10.4	40.0	13.0	31.2	13.2	27.1	8.4	15.3
Perennial ryegrass (D)	15.3	15.8	19.8	9.0	32.5	23.0	29.6	0.9	38.0	6.0	12.5
Meadow fescue	31.3	27.7	35.7	18.9	43.2	21.1	43.9	16.4	44.4	14.9	38.5
Cocksfoot	14.1	20.9	15.5	12.0	26.4	20.2	11.1	9.7	16.8	5.2	10.1
Timothy	30.9	26.2	22.9	11.4	51.4	36.6	45.8	46.2	40.6	18.1	53.8
SED	7.98	13.77	8.71	11.27	10.85	10.5	7.84	12.3	7.73	3.82	11.16
F pr.	0.202	0.771	0.328	0.904	0.368	0.442	0.081	0.147	0.132	0.124	0.087
Grand mean	20.6	20.6	22.0	12.3	38.7	22.8	32.3	17.3	33.3	10.5	26.0

APPENDIX 6

"GENSTAT 5" PROGRAMMES

Typical "Genstat 5" programme for experiment 1 - Analysis of variance

```
Genstat 5  Release 2.2  (Vax/VMS5)            10-MAR-1992 15:06:49.65
Copyright 1990, Lawes Agricultural Trust (Rothamsted Experimental Station)
job "b_field PQUAD88"
units [nval=480]
factor [lev=4;lab=!T(CG0,CG1,CG2,CG3)]  graze
factor [lev=4;lab=!T(A,B,C,D)]  clover
factor [lev=2;lab=!T(tetra,diploid)]  ploid
factor [lev=5;lab=!T(ve,e,i,l,vl)]  mat
factor [lev=10;lab=!T(ga,ba,fa,co,be,fr,pe,mo,pa,br)]  prg
factor [lev=3] rep
factor [lev=40;val=(1...40)12]  plt
open 'treats.dat';ch=2;filetype=input
read [ch=2] plot,rep,graze,prg,clover
close 2
calc ploid=newlev(prg;!(1,1,1,1,1,2,2,2,2,2))
calc mat=newlev(prg;!(1,2,3,4,5,1,2,3,4,5))
variate plot,grass,clov,weed,earth
   open 'PQUAD88.';ch=2;filetype=input
   read [ch=2] plot,grass,clov,weed,earth
   close 2
   block rep/graze/plt
   treat graze*clover*ploid*mat
   anova [fprob=yes] grass,clov,weed,earth
endjob
stop
```

Typical "Genstat 5" programme used in experiment 2

Analysis of variance

Genstat 5 Release 2.2 (Vax/VMS5) 16-FEB-1993 13:36:02.08


```
job "Longholm cores Oct 91"
units [nval=45]
factor [lev=3;lab=!T(CG1,CG3,CG2)] graze
factor [lev=5;lab=!T(PRGT,PRGD,MF,COCKS,TIM)]grass
factor [lev=3] rep
open 'Ltreats.';ch=2;filetype=input
read [ch=2] plot,rep,grass,graze
close 2
variate plot,AstolonL,BstolonL,stolonL,tillers,AMGtillers,\
 AstolonW,BstolonW,stolonW,AGP,BGP,GP
  open 'moct91.prn';ch=2;filetype=input
  read [ch=2] plot,AstolonL,BstolonL,stolonL,tillers,AMGtillers,AstolonW,\
  BstolonW,stolonW,AGP,BGP,GP
  close 2
  calc agpm=(AGP/AstolonL)
  calc bgpm=(BGP/BstolonL)
  calc tgpm=(GP/stolonL)
  calc awl=(AstolonW/AstolonL)
  calc bwl=(BstolonW/BstolonL)
  calc twl=(stolonW/stolonL)
  calc asts=(AstolonL/stolonL*100)
  block rep/grass/graze
  treat grass*graze
  anova [fprob=yes] AstolonL,BstolonL,stolonL,tillers,AMGtillers,\
  AstolonW,BstolonW,stolonW,AGP,BGP,GP,agpm,bgpm,tgpm,awl,bwl,twl,asts
 endjob
 stop
```

Typical "Genstat 5" Programme used in experiment 2 - Regression analysis

Genstat 5 Release 2.2 (Vax/VMS5)21-AUG-1993


```
job"tillers v clover"
units [nval=9]
open 'prgd.';ch=2;filetype=input
read [ch=2]
prgtsl,prgttn,prgdsl,prgdtn,mfsl,mftn,cockssl,cockstn,\
timsl,\timtn
close 2
corr[pr=corr]prgtsl,prgttn
graph[nrow=21;ncol=51]y=prgtsl;x=prgttn
model prgtsl
fit prgttn
corr[pr=corr]prgdsl,prgdtn
graph[nrow=21;ncol=51]y=prgdsl;x=prgdtn
model prgdsl
fit prgdtn
corr[pr=corr]mfsl,mftn
graph[nrow=21;ncol=51]y=mfsl;x=mftn
model mfsl
fit mftn
corr[pr=corr]cockssl,cockstn
graph[nrow=21;ncol=51]y=cockssl;x=cockstn
model cockssl
fit cockstn
corr[pr=corr]timsl,timtn
graph[nrow=21;ncol=51]y=timsl;x=timtn
model timsl
fit timtn
stop
```